

491
48
Hof 9

COAL MINE ENGINEERING

BY

FREDERICK WILLIAM RICHART, B.S., 1891

THESIS

LIBRARY
UNIVERSITY OF ILLINOIS
CHICAGO

FOR THE DEGREE OF MECHANICAL ENGINEER

IN THE
GRADUATE SCHOOL
OF THE
UNIVERSITY OF ILLINOIS
PRESENTED JUNE, 1905

UNIVERSITY OF ILLINOIS

May 26, 1905 190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FREDERICK WILLIAM RICHART, B.S., 1891

ENTITLED COAL MINE ENGINEERING

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Mechanical Engineer

HEAD OF DEPARTMENT OF Mechanical Engineering

39

CONTENTS

1. PRELIMINARY
2. PROSPECTING
3. LOCATION OF SHAFT
4. SINKING
5. DESIGN OF TOP WORK
6. PUMPING
7. POWER PLANT
8. DESIGN OF BOTTOM
9. CARS AND HAULAGE
10. TIMBERING
11. METHODS OF MINING
12. VENTILATION

PRELIMINARY

The preliminary work, incident to the development of a coal mining proposition, is for the express purpose of deciding to a degree at least, the commercial feasibility of the project.

If the preliminary work leads decidedly to the conclusion that it is, or is not feasible, the object is accomplished. It may however, be a difficult matter to decide from a reasonable amount of preliminary work, in which case the judgment of the engineer will be necessary, to determine whether it is worth while to expend further time and money in extensive investigation, or even in actual working plans.

The character of the preliminary work will depend entirely on the development, and obtainable knowledge of actual working conditions of the field.

REPORT:- The preliminary work will consist of written report, together with a map of the field under consideration.

This map will show all of the lands either owned or contemplated, and all obtainable details that can best be shown on a map.

The map and report will cover the following items;

Geology

Extent of Territory

Transportation

Topography

Product and Markets.

GEOLOGY:- This will include an examination of all working seams. A minute examination of the strata immediately above and below the coal, and all the visible characteristics of the coal seam itself should be noted. Note in the roof, kind of material,

whether clay, shale, slate or rock. Whether it is soft or hard, strong or weak, stratified or solid. If solid note especially if there are irregular water seams where no cohesion exists. Does the material disintegrate on exposure to air.

The coal seams must be examined from top to bottom, noting the appearance, hardness, location and kind of impurities, whether it is wet or dry, and enough analyses to form a fair average. The impurities usually found are slate, gypsum in small flakes, and iron pyrites. Occasionally streaks of clay and other impurities may be found.

It is often of considerable interest to note in particular the material which forms the bottom. If soft it may heave and partly close the entries and rooms unless considerable pillar be allowed. Indeed it may determine the method by which the coal is to be worked.

In an undeveloped field this information may not be obtainable. In that case less reliable information can be obtained by an examination of the outcrop of the veins, and later, of the materials from prospect holes.

EXTENT OF TERRITORY :- As a matter for future reference as well as for immediate use, it is desirable to give the known or surmised extent of territory covered by the coal seams in question. The limits are to be shown on the map and the facts and reasons given as to why it is known or supposed to be the limit of the field.

TRANSPORTATION :- Under this heading, locate all wagon roads, railroads and navigable streams and give distance from nearby towns and large cities. Note general condition of roads and the ability and disposition of railroads to furnish cars and transport the product.

TOPOGRAPHY :- Note the general character of the surface, location of streams, lakes, ponds and natural forests. Any unusually level, hilly or mountainous sections are to be noted on the map. Where government topographical surveys have been made a topographical map should be secured. It may be even necessary at some period in the examination or development of the property, to make a topographical survey.

PRODUCT AND MARKET:- The questions of cost and selling price of product are what determine the commercial possibility of any enterprise. The preliminary report must contain the fullest possible data of costs or possible costs, operating expenses, freight, switching and demurrage rates, and selling prices of the different grades of coal. A general idea of the mining conditions and possibility of competition, its effect, and methods of eliminating or overcoming aggravated cases. Note the usual and possible markets, and prices for different grades of coal and coke.

PROSPECTING

OBJECTS:- The term "prospecting" as usually applied to coal mine operations, merely signifies drilling into the ground to determine the character and thickness of the coal veins, as well as the underlying and overlying strata. In its broader use, it will include the following items:-

- 1 Surface
- 2 Drilling
- 3 Examination of Strata

The object of the examination being to obtain a definite knowledge of the characteristics and environments of the vein to be worked.

SURFACE EXAMINATIONS:- Surface examination will locate all the available natural water supplies, and possible locations for ponds. The character of the soil can present no bearing in itself, except in the matter of foundations for top works and buildings, and the suitability of soils and clays for making tight dams. It is well to bear in mind that for mines of large capacity some of the foundations must sustain heavy weight, and soft, spongy, or swampy ground must be avoided, thoroughly drained or piling used.

DRILLING:- The object of drilling is to determine the thickness and hardness of the strata and to bring to the surface a core of the material passed through, for the purposes of physical and chemical examination. It is only by this means that an approximate idea of the general characteristics of the field may be obtained.

In a new field there are many important features that drilling will fail to bring out. Some of the important things that cannot be determined are;

- 1st Will the mine when developed be wet or dry?
- 2nd If slate be directly over the coal will it be solid, stratified or be filled with irregular seams.
- 3rd Kind and location and direction of cleavages in the coal seam.

If the immediate vicinity has working mines, where the working conditions can actually be observed, some of the above mentioned information may be inferred with reasonable certainty, by an examination of the core from a diamond or rotating drill, when taken together with actual observed conditions in nearby working mines.

CHURN DRILL:- The churn drill is a primitive, and now almost wholly discarded tool especially in new fields. As the name implies, it is a steel bar flattened and widened at one end, suspended from a rope at the other, and churned up and down, either by hand or mechanical power. A later device uses rods screwed together, the whole distance drilled.

The drillings or material thus broken up is kept out of the way of the drill, by being mixed with water. If the strata passed through are not water bearing, water must be furnished artificially. The drillings which furnish the only clue to the material passed through, are brought to the surface by a sand pump. The sand pump is a long bucket with a valve in the bottom. With this sort of a drill it is difficult to tell the exact beginning and ending of any stratum. The driller must practically tell by the "feel" of the tools as they pass from one stratum to another. Even though he may estimate very closely as to the time of passing into a new material, when a rope rig used it is impossible to measure with exactness the depth of the hole or the thickness of any stratum.

There is a modification of the churn drill which combines the sand pump with the drilling machine. In this machine, the drill rods are hollow and extend entirely to the surface, near the bottom is a valve and attached to the top is a hose leading to a bucket. As the machine operates, the drillings are carried up with water and deposited in the bucket. This avoids the necessity of taking the drill out to clean the hole, and shows at all times just what material is being passed through. It will indicate a rough approximation of the point where a new stratum is reached. As is apparent, it takes some time for the drillings to reach the surface and the material from different strata becomes more or less mixed so that

indications are uncertain.

It is impossible to get even an approximate analysis of the coal vein by this method of drilling. There are two reasons for this difficulty. First, it is mixed up with materials from adjoining strata and it is impossible to get a true or pure sample. Second; being ground up and mixed with foreign materials it is necessary to wash it to remove them, this washing removes sulphur and ash that naturally belongs in the coal and makes the analysis show up better than it should.

CORE DRILLING:- Core drilling is accomplished with either of two kinds of machines. The diamond drill which is the more usual type used, and the rotary drill with steel cutter. Both are alike in that they furnish a core of all material that is not broken up by the jarring action of the drill, or washed away by water.

In each the principle is the same but the details of construction different. The cutting part of one is a cylindrical steel saw, screwed to the lower end of a hollow tube, revolved very slowly, and making a chattering cut in hard material. The original idea was worked out in the Davis Calyx drill. The diamond drill has a series of low grade diamonds set in one end of a cylinder, which is screwed to the lower end of the drill rods and revolved at a moderate speed. The feed is by hydraulic pressure so that the speed of cutting is proportional to the hardness of the material passed through.

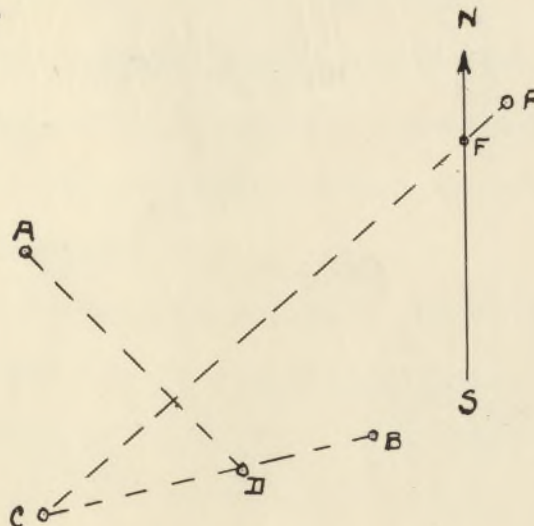
With both drills the cuttings are washed to the surface by water forced down the drilling rods by a pump; connection being made by a rubber hose and revolving joint. The size of the core depends on the kind of drill. Diamond drill cores usually run 1-1/4" to 3" in diameter, steel drill cores up to 6" or even more.

COST:- The cost of churn drilling for shallow depths, say to 150 ft, will run \$1.00 to 1.50 per foot. Diamond drilling to 600 ft \$2.00 to \$3.00 per foot with all fuel and water furnished by the party having the drilling done.

PITCH OF VEINS:- The pitch or dip of veins is ascertained by connecting all the bore holes by lines of levels. There are usually local irregularities, so that the vein though having a general pitch may not be a plane. Assuming that the vein is regular the amount and direction of pitch is easily calculated from three bore holes. In the sketch (Fig /) let the bore holes be represented by A B and C, and N S be a meridian line. Suppose B be deepest and C the shallowest hole. Connect C B and find by porportion a point D that has the same elevation as A . Connect A D this line is level. Draw a line C E at right angles to A D and extend it until it intersects N S at F . This is the direction of the pitch, and the angle C F S is the amount . The pitch is found by this formula;

$$\frac{\text{Depth at A} - \text{Depth at C}}{C H} = \text{Sine angle of pitch.}$$

It must be understood that the depths must all be from a given or assumed datum plane.



ANALYSES:- The purpose of making analysis is to determine the heating value ,character, and amount of impurities in the coal. The proper method would be to take the whole core from top to bottom, grind it up , quarter it and repeat till a suitable sized sample is obtained. The prospector will send it to a reliable chemist and have two analyses made from each core for a check. It is desirable to have proximate analyses with the sulphur separately determined, and also calorimetric determination of the heat units. Ultimate analyses are hardly necessary . The records should be tabulated for comparison, as the same vein will not give exactly uniform results from different locations.

With the proximate analysis the proceedure is as follows but may vary with different chemists. In all cases the moisture is the first item to be determined and this may be accomplished by first weighing out a small quantity of coal and subjecting it to enough heat to drive off the moisture after which it is weighed again. If this coal is subjected to a still greater heat the gases or volatile matter is driven off, after this the remaining coal is subjected to heat again and with the aid of oxygen the fixed carbon is consumed leaving us the ash. In the process named above the sulphur is driven off as a gas together with the volatile matter. The sulphur is determined by a separate proceedure. Of late some chemists have divided the volatile matter into still another division called water of combustion.

In the case of the calorimetric analyses the process varies with the make of calorimeter but the determination is based upon recording the amount of heat evolved in combustion of a small quantity of coal , which heat is expressed by aid of formulae into B.T.U.

LOCATION OF SHAFT

The economical location of hoisting shaft is a matter of relatively great importance. By reason of particularly unfavorable conditions it may be much cheaper to sink at some particular point in preference to some other but a short distance away. On the other hand the more favored condition for sinking may involve higher operating expense that will continue throughout the life of the plant. All of the influencing conditions should be given consideration in proportion to their importance.

HAULAGE:- With relation to the haulage problems, there are two influencing factors. The first consideration would place the shaft in the center of the field, as giving the minimum average distance for pulling the material. A further consideration will take into account the grades that will exist in the hauling entries. These grades may be approximated with a fair degree of accuracy from elevations taken at the prospect drill holes. It is evident that it will be advantageous to have as much of the grade as possible in favor of the loads. It must, however, be borne in mind that some fields may dip entirely in one direction, and to place the shaft on one side would be wrong, as it would make the average haul unnecessarily long. A reasonable average under such conditions, other things being equal, would be to place the shaft one third the distance from the low side of the field. This is, however, not an infallible or fixed rule to go by.

PUMPING:- In many locations the pumping problems are quite as serious as haulage. In fact there is no item other than poor top, that can run up the cost of production, and hamper legitimate work to a greater extent than mine water improperly taken care of.

Where general conditions are well known it is not so difficult to decide before hand, the best steps to be taken. In unknown fields it is well to be on the safe side. It will always simplify the pumping problems to have as much water as possible drain towards the shaft by gravity. This point, like all others involved is only entitled to its fair share of weight, but often being an item of large and constant expense, must have serious consideration.

RAILROAD CONNECTIONS:- The point at which railroad connection is made is merely a matter of cheapest track cost and should be considered only from point of first cost. The difference in maintenance is only a matter of keeping up a small amount of track, that does not carry much traffic.

LOADING YARDS:- This is another point for first cost consideration. All track scales must have pits drained. The topography may be such that there will be but little grading required. It is possible to preserve a certain shaft location, and yet have many yard locations to consider. Usually the yards may be readily adjusted to the shaft, and the yard location is not a controlling feature, except to a limited extent.

WATER SUPPLY:- This is a problem of no little importance, though not necessarily a controlling feature. An abundant supply of good water is always desirable, at the same time it may readily be pumped for a very considerable distance at no great expense, where electric power is available, except as to first cost.

The whole proposition comes down to a point of averaging up all conditions and selecting the location that will be most profitable for the capital invested. At times it seems almost necessary to choose for cheap first cost regardless of all other considerations.

Where the better judgment is allowed to prevail, low operating costs and results obtainable will be the controlling elements.

SINKING

SHAPE OF SHAFT:- In the European countries there are many practices that are not at all in common with those in United States. In Europe there are round, polygonal and rectangular shafts, while in this country they are nearly always rectangular.

The kind of material above the coal has no doubt a considerable influence on the shape, as also has the material used for lining. Brick or iron lined shafts are common in Europe, and the round shape lends itself best to this material. It is readily understood that any circular lining built of a given quantity of material will be stronger than a rectangular one. The fact that there is more soft material above the coal than in this country may also account for the shape so common in Europe.

Among the items that have made the rectangular shape so well nigh universal here are, cost of iron or steel, scarcity of brick, and cheapness and abundance of timber, together with the desire on the part of the engineers to utilize all the space in the shaft.

SIZE OF SHAFTS:- In most states of the Union a ventilating and escape shaft separated entirely from the hoisting shaft is required. Where there are closely adjoining properties and where the depth to the coal is considerable, a single air shaft is sometime made to do duty for more than one mine. The size of the airshaft is usually such that there is room for two separate compartments.

One a man-way or escape shaft, and the other for air. The escape compartment is large enough to accommodate a stairway or small hoisting cage, and the airway should not be less in cross section than the entries leading to it.

The hoisting shaft is usually divided into two, three or four compartments. Two of these are hoist ways, while the others are used for ladder way, steam, water and air pipes, electric wires and haulage cables.

The size of hoist way is dependent on the size of the pit cars, while size of pit cars depend on the size of out put desired, and on the thickness of vein. The capacity and size of cars is to be determined by methods given in chapter ten. The length of hoist way should be about 6" greater than total length of car, and its width twice the thickness of guide plus extreme outside width of car, plus 12" to 18". The size of pipe and ladder ways, will depend entirely on what is to be accommodated in the space. It is good practice to have all pipes and ladders in the same space, as the ladders afford a good working scaffold from which to install or handle pipes and wires. This third compartment is usually partitioned off from the hoist ways and used for an airway during sinking and development, till connection is made with permanent air shaft.

MACHINERY:- The equipment used for sinking will depend entirely on the depth, material to go through and the methods used. For ordinary conditions of clays, shales and rock and a moderate amount of water, shaft 1000 feet deep or less, the equipment would approximate as follows;

Boilers with fixtures and feed pump, 20 to 80 H.P. depending on depth.
Hoisting engine to lift 1000 to 2000 pounds 10 to 40 H.P. friction or reversing, geared drum.

Hoisting rope $5/8"$ or $3/4"$ and 30" sheave .

Three wooden or steel hoisting tubs to hold $1/3$ to $1/2$ ton.

One truck to take material from shaft.

Steam, air or hand drills for rock, depending on the amount of rock.

Powder dynamite, caps and electric battery.

Shovels, spades, picks, carpenters tools, blacksmith outfit, and other hand tools and a line of pipe fittings and supplies.

Where there is but little water, it can best be taken care of by hoisting in tubs, but if there are large quantities it will have to be handled by some kind of pump. The most convenient form being a vertical sinking pump, steam or electric. A small ventilating fan will hasten the clearing of the shaft after firing shots.

Where work is carried on at night it is well to have a small electric light out-fit.

BEGINNING WORK:- The shaft is staked out by transit, setting eight stakes about 4" square and 4 or 5 feet long, driven down until solid. A nail center is put in each driven to 1/4" of the head. Lines stretched across these nails locate the sides of the shaft. This is made to the inside or finishing size of shaft. A plain head frame, similar to Fig 2 is set up over the location of shaft. The excavation is made larger than the finish size by the thickness of the timber with which the shaft is to be lined.

ORDINARY METHODS:- Usually the clays and shales passed through are worked up with picks or powder, shoveled up and hoisted out in tubs. These materials usually stand several feet, so that the material is excavated for say ten feet then timbered up, and the process repeated until hard material is reached. The shaft is kept straight by plumb lines hung a definite distance from the finishing line of the corner, measurements are taken from the plumb line when excavating and timbering.

HARD MATERIALS:- When slates and rock are encountered, blasting holes are drilled either by hand or steam drill. Hand drilling is very slow and expensive.

Steam or air drilling is more rapid and less expensive where the amount of material will justify the equipment. Sinking specifications sometimes require the drilling to be kept 6" to 10" from the finishing line, where high explosives are used, with the idea in view of keeping the wall solid. This necessitates a great amount of hand work, and is entirely unnecessary where the shaft is lined from top to bottom. The only reason for this practice, applies where the rock part of the shaft is unlined, and shattered fragments might sooner or later work loose and fall, possibly injuring some one.

Of the several explosives used in this kind of work, blasting powder and dynamite are the most used. Powder is used for hard clays, shales and soft rock, dynamite for hard rock and slate. Dynamite being exploded by detonation and also on account of freezing at a high temperature, is undesirable. There are other explosives, jovite for instance that is much less dangerous to handle, while accomplishing the same results. It is always best to use as electric battery to set off explosives as there is no danger of any mishap from premature shots, such as catching a man in the shaft when the blast is fired.

The strength of the explosive to be used is a matter to be determined by experience, or to be obtained from some one familiar with the workings in the locality.

QUICK SAND:- Soft clays, water bearing gravel or quicksand, requires special treatment. The usual methods are caisson, sheet piling and freezing. The caisson method consists of sinking a built up caisson or lining through the soft stratum to solid ground. This caisson is built up of heavy timbers bolted or drifted together, made water tight if necessary, and having a sharp edge of wood or iron at the bottom to cut through the ground.

It may be sunk from the surface down to and through the soft material Fig 3 ,or the shaft may be sunk in the ordinary way except larger, to a point near the soft material, and a caisson built inside of this to sink through as in Fig 4 . An objection to this method is that for a few feet of the bottom of the enlarged part of the shaft no buntons or cross struts can be put in, and that part may have to be lined with the heavier timbers.

The essential points to be observed are that the timbers be heavy enough to withstand the pressure, and that the caisson itself be stiff vertically and kept absolutely vertical. It may sink of its own accord or it may have to be forced down by jacks or weights. Another method that may be used where the stratum of soft material is not thick, is to sink as usual and to finished size, to a short distance above the soft material, then build a caisson the same size the part already timbered, and directly below it. A shoe is fastened to the bottom and the caisson forced down by jacks, being built up on top as the work progresses.

Sheet piling of wood has been used in Europe, and recently interlocking steel pilings extensively and successfully used in this country. The method of use is to sink by the ordinary method down to near the quicksand, then set the piling inside the shaft and hold it vertically by a wooden guiding frame placed on the inside of the piling. Each piling is driven down in turn about three feet, till the circuit is made. This is repeated till the piling is through the sand, the inside is then excavated and timbered inside the piling to the finished size of the shaft. Figure 5 shows a shaft sunk in this way. It is necessary to protect the top of the piling by a forged head while driving or the end will be battered and bent out of shape, and the hammer will be grooved so it will not strike square.

The hammer is similar to a pile driver hammer but so made that it will drive one sheet singly, and weighing 1500 to 2500 pounds. There are two methods of freezing through quick sand. In each a series of holes is drilled around the shaft, about four feet apart and about two feet from the shaft, and a pipe with closed bottom driven down the hole through the sand. In each large pipe is also a smaller pipe extended from top to bottom. The lower end of this small pipe is open. In the Poetsch system, the whole system of pipes is connected in series, the small pipe of one to the large pipe of the next pair, making a complete circuit. Through this system of piping the brine is pumped. It is necessary to have all joints tight as a leakage of brine would prevent freezing.

The Gobert system differs in some of the details, from the Poetsch. The chief differences being the use of spiral inner pipes, with small perforations, and the use of liquid ammonia forced down the inner tubes and gassing off on escaping to the outer tube. No brine is used. An essential condition in both systems, is to have the bore holes vertical, in order to have the frozen sheet continuous and uniformly thick.

TIMBERING:- It is essential to use timber that will resist decay for a long time. The conditions which tend to rot timber quickly are to be alternately exposed to wet and dry. This condition usually exists in the upper part of a shaft, while lower down it may be continuously wet. Timber that is submerged in water or kept thoroughly wet will not rot, so that in wet places timber may be used that would be absolutely useless in another location. The timbers best suited for shaft linings are probably white oak and cypress. The size of the timber is a very important matter for consideration, in fact it is one of the vital parts of the

equipment. There is not, in the writer's knowledge any published data on this subject on which to base calculations. He has however observed that timbers 5" thick with a 9'-6" clear span have shown signs of weakness and considers that 6" is the minimum thickness for that span in clay, using white oak timbers.

Taking the formula $D = \frac{5 W L^3}{384 E I}$ and transposing for W we get
 $W = \frac{384 D E I}{5 L^3}$

Take the following case where ,

$$D = 3/4"$$

$$b = 12"$$

$$E = 1500000$$

$$d = 5"$$

$$L = 9 \frac{1}{2}' = 114"$$

$$I = \frac{b d^3}{12} = 125$$

Substitute and solve, $W = 7290\#$ or $767\#$ per square foot.

This particular thickness, 5" has shown signs of weakness and it would appear advisable to design the timbering for a pressure of 750 to 800# per square foot. The depth below the surface at least down to 75 feet in clay, does not seem to make much difference.

Timbering in soft clay or quick sand will have to be made on the basis of pressures calculated from the surface and will be about 100 to 125# pressure per square foot, per foot of depth. That the pressures in quick sand are enormous is shown by the fact that very heavy timbers have been twisted, forced out of shape and broken by the pressure.

It is well to bear in mind the possibility of having to retimber a shaft, if it is to stand for many years. This is not a difficult thing to do in stiff clay or slates, and in that case requires no particular forethought. Where there is difficulty in sinking in the first instance, every precaution should be taken to do the work in such a way as will facilitate the retimbering in case it must be done.

This kind of work is sometimes lined with concrete of sufficient thickness to withstand the pressure. This is sometimes reinforced with steel bars. This kind of construction although expensive, makes a permanent job, and except in case of some unforeseen accident, there is never occasion for relining the shaft.

STEEL LININGS:- There has been at least one instance of a steel lined shaft. While there is a bare possibility that this may prove more permanent than wood, its necessarily greater first cost is likely to keep it from becoming popular until timber is very much more expensive. There arises also the question as to whether it will not rust out. At the present time the subject of the preservation of structural work above ground is provoking a good deal of discussion and experiment. The amount of obtainable data in regard to the preservation of steel under ground, is practically nothing.

DESIGN OF TOP WORK

WATER SUPPLY:- Abundance of water is necessary. If no stream is near enough to be considered, a large pond is the next best supply. Before beginning an earthen dam, all vegetation and a foot of the surface should be removed, then the dam built up in layers of earth free from vegetatable matter, otherwise it is likely to leak. Spillways must be provided about two feet below the top of the dam, and cut out of solid earth entirely away from the dam itself, or what is better, built of concrete. When dams are necessary in running streams, they are to be built of timber, rock, or concrete. The amount of water required must be determined by the various uses to which it is to be put.

YARDS:- Grades of 1 % for empties and 0.6 to 0.8% for loads are about right for yards, with straight or very lightly curved tracks. Where possible, arrange for the first loaded cars out to have an up grade to stop on , as they sometimes get past control through defective brakes. Avoid curves sharper than four degrees, if possible, keeping in mind the fact that cars must be handled largely by hand, and sometimes get very stiff in cold weather. Use split switches, and frogs not of higher number than seven. Make width of fills for single track not less than 12 feet on crown with sides 1 1/2 to 1 slope. For high fills make crown wider. For cuts make bottom not less than 16 feet wide, side slopes 1 to 1 or 1 1/2 to 1 according to the ground.

Car hauls, consisting of six to ten horse power motor or engine and wire rope may be installed in locations where it is impossible to get the necessary grades to handle cars by gravity. The capacity of the yards will depend on the out put of the mine, and the frequency of switching. It is usually necessary to make the storage room for both loads and empties large enough for a full days run, which is equivalent to about one foot of clear track for each ton.

Track scales are usually installed directly under the tibble, or at a point where all the loading tracks converge into one single track. The track arrangement should be such that the scales are not passed over by the locomotive . Of the various methods of installing scales, the use of concrete for foundations and retaining walls of pit is the most satisfactory. The pit must be drained, preferably with sewer tile as large as 6" in internal diameter, and the joints cemented.

TIPPLE:- The tipple is the building used for weighing, sizing and delivering the coal to railway cars. In the anthracite field called a breaker.

The foundation in small and cheaply built plants, are often of wooden blocks or mud sills. Concrete is the most satisfactory material for this purpose, and of all satisfactory material, the most cheaply built. It is the only material that can be handled entirely by cheap labor and yet give reasonably good results. Use only Portland cement. There are many different American makes that are entirely satisfactory. A good proportion for ordinary work with river sand and broken stone is 1-3-5. If the foundation is for machinery and subject to continued or violent shocks, use 1 1/2 parts cement.

Tipples are usually built of wood and in great variety of designs. The older structures were built of square timbers held together with comparatively small rods and bolts, and with little thought given to proportioning a member to the work it had to do, or the convenience or ease of replacing a piece if broken. The later designs are better proportioned to resist the strains coming upon them, and the tendency is for built up members of smaller cross section, with splices so arranged as to break joints. The members are bolted together and so arranged that any member can be replaced if necessary, without difficulty, and any looseness from shrinkage of timber can be taken up by bolts. Possibly the best protective paint is graphite. Drawings # 6 & 7 show side and end elevations of a wood frame tipple.

Steel tipples are becoming quite fashionable although the wisdom of putting up an unprotected steel frame in close proximity to a wooden washery or bin building is certainly doubtful.

It is more expensive than wood, may be injured by fires or explosions and is not any better suited to the business than wood. They are usually painted with graphite, and wherever used the covering should be galvanized corrugated steel roofing. Drawing # 8 shows a steel structure. There is a later and perhaps more rational idea in steel designs. Fig 9 gives the idea. It consists of bolting the A shaped frame to foundations heavy enough to hold the pull. The guides only need the necessary support to hold the cages in position and to hold the weight, in case the safety catches are called on. The ordinary strain to come on the Guides is very small except at the dumping point, if self dumping cages are used.

The scales used for weighing the coal as it comes from the pit, are 4 to 12 ton tippie or wagon scales, according to conditions. The scale must be heavier than required for the amount weighed, to withstand the shock of dumping coal, in cases where coal is dumped into a hopper to be weighed. The hopper is usually swung from the scale frame by rods. The installation of scales only require that the levers be level, the suspending links or rods be vertical, and knife edges sharp and having a good bearing. The platform or hopper is to be stayed to prevent unnecessary swinging. The movement must be absolutely free vertically.

The screens form the vital part of the tippie, because the price depends on the cleanness of the coal. There are three forms in common use, bar, shaking, and revolving.

Bar screens are the most inefficient, are not capable of cleanly separating any size of coal but lump, and are fast disappearing except where used for that single purpose. They are objectionable on account of the high velocity given to the coal, so that it breaks up on falling into the car. The pitch of the bar screens is about

30 to 33 degrees.

Shaking screens are used alone or in conjunction with revolving screens. In order to get results, the first requisite in any screen is for the coal to reach the screening surface. Without this condition it is impossible for the coal to be screened. The shaking screen makes a better separation than the bar screen, because the coal is retained on the screening surface for a greater length of time, and has a better opportunity to spread out and become thinner. The chief difficulty in the way of successful screening where there is a large output, lies in the fact that a large amount (2 to 4 tons) is dumped on the screen in a lump. This will amount to from 80 to 160 cubic feet and as it must spread out to an average of less than six inches thick in order to screen properly, the screening cannot be done unless some means is provided to distribute the coal.

The most successful means known to the writer, is a plan devised by himself. The principle is shown in the side elevation of the wooden tippie. It consists of a hopper into which the coal is dumped, and from which it is drawn by a wide drag or apron conveyor running at such speed as to feed the output continuously on the screen.

There are several methods of connecting up and hanging screens.

A good method is shown in drawing # 10, but if the screen were hung from overhead timbers by a similar method it might be more satisfactory. The features to be embodied in a shaking screen are;

Lightness and yet retain strength.

Perforated plates not less than 1/4" thick.

Screen in two parts moving in opposite direction.

Spring connection to eccentric to lessen shock.

Proper speed and pitch.

Figure the output of mine at 40 cubic feet per ton, and speed over screen at 80 to 100 feet per minute, and an average depth of 4" for the coal, then allow 25% for time lost and figure width of screen necessary. Design it to hold up the weight and resist the shocks. The bottom plates must be $1/4$ " thick to give reasonable wear. The reason for making the screen in two parts is obvious. It almost destroys the tendency to produce vibration. In as much as part of the coal does not reach the lower screen, it may be made 10% heavier than the upper in order to average up. Spring connections are made at the crosshead end, see drawing # 11.

There has been no formula worked out by which to figure out the size of springs to be used. It is desirable to allow about $1/8$ " of movement at the end of the stroke. The springs usually have five or six coils, with the diameter of wire depending on the weight, and speed of screen, length of stroke and diameter of coil.

The ordinary inside diameter of the coil is $1\ 1/2$ " to $2\ 1/4$ ". For conditions as given below, a spring with a cross section of $1/9$ or $1/10$ square inch for each 1000 pounds weight of screen will give good results.

It has been found that a speed of 120 R.P.M. stroke 5", and pitch of 1 in 4.5 gives good results with ordinary dry coal. Wet coal will require more pitch. The speed is necessary to jerk the large lumps out of the perforations.

Revolving screens are largely used for separating screenings into grades, and are very satisfactory for the the very reason that all coal gets a chance to get at the screening surface. They slope about 1" per foot and have a peripheral speed of 200 to 250 ft. per minute. They will take care of two tons per square foot per day of 8 hours.

They are sometimes made polygonal instead of round, but with no advantage except perhaps with wet coal. Fine sizes of coal if wet clog up the perforations. Perforations less than 5/8" are useless in damp coal. The only successful way to screen fine sizes of wet or damp coal is to wash it through with sufficient water to carry the coal bodily.

Power used for driving screens and other appliances around the tibble is usually furnished by steam engine, but would be much less trouble if motors were used, to be furnished with power from single central plant.

Boxcar loaders are much in evidence in the west. There are several successful loaders, of which the Smith is very expensive, and probably no better than some others; the Bond is the least troublesome and will handle a larger output than any except the Smith. The

Ottumwa is looked on with much favor and will probably break less coal than any other unless it be the Victor; the Victor and Christy are somewhat similar, with the Victor probably in the lead.

In principle, the Smith tilts the car on end and the coal is poured in; the Bond has revolving blades or shovels that throw the coal to the end of the car; the Ottumwa is a single flight conveyor that alternates from end to end of the car; the Victor is a conveyor that loads one end of the car, then changed to the other; while the Christy is a short reversable high speed conveyor that occupies only the center of the car and must throw the coal to the ends.

WASHERIES

The object of washing coal is to remove impurities. The advantages are the removal of ash, sulphur and fluxing or clinker making material.

It reduces freight and haulage expense and furnace repairs, and enables a higher rate of combustion to be maintained under the boilers. For coking coal it is desirable to take out all the impurities possible, and necessary to reduce the sulphur below 1%. For domestic use it is much cleaner, less refuse, no clinkers. When stored in large quantities there is no tendency to spontaneous combustion or the generation of heat.

PRINCIPLES:- The principle on which all washing is based is the difference in specific gravity between the coal and impurities. The four methods used in making separations are trough, tables, stirrer, and jig.

The trough in its crudest form is a stationary trough set at an incline lengthwise with cleats across the bottom. The coal is washed down and out at the end while the impurities are caught by the cleats.

TABLE :- The table is a vibrating trough or table with riffles across the bottom, this table is brought violently against a buffer or post which causes the impurities to be thrown up hill and out at one end while the coal is washed out the other.

STIRRER:- The stirrer consists of an inverted cone shaped vessel into which the unwashed coal is discharged, a stream of water is forced in at the bottom; revolving stirrers keep the mass mixed up; the coal is floated over the top, while the impurities settle to the bottom and are drawn off.

JIGS:- The jigs consist of a box in which there is a partition. On one end is a loosely fitted plunger, on the other a means for separating the coal and impurities, and ^{trough} into which coal and water are discharged. The jigging motion imparted to the water by the plunger causes a separation of coal and impurities, the coal being washed over and the impurities settling to the bottom, and being

removed.

There are many modifications of all these, but only four systems are in extensive use, they are the Campbell, Stewart, Luhrig and Robinson-Ramsay.

CAMPBELL:- The Campbell washer is a vibrating table about 8ft long and 30 inches wide, swung from above by rods. The supports at the discharge end are made adjustable so that the table can be given a pitch to suit conditions. There is a solid bottom and a false bottom of riffles, shown in Fig 12. The coal is fed to the table through a spout from the storage bin above, the quantity being regulated by a small stream of water. Water is also supplied to the table by a stream of water discharged behind the coal. It is important that this water be discharged at two or three points across the width of the table. The volume of water must be sufficient to carry the coal and float it over the end into the trough, the coal may be conveyed or floated to some point to be elevated or discharged into bins.

The peculiar motion given to the vibrating table is obtained by a cam and a rocker bearing, which gives a variable length to the rocker arm. This makes a slow forward motion and an accelerated backward motion striking the bumping post a hard blow, and throwing the heavy impurities up hill till they finally fall over the upper end, and are conveyed away. The table makes about 80 strokes per minute. The capacity is about 75 tons per ten hours for each table. One peculiarity of this washer is, that the inventor claims to get best results, the coal should be unsized before washing. It is quite likely that a greater quantity of unsized coal may be put over a table in a given length of time than if sized.

It is, however, well known that the size of the coal or impurities has a great influence on its action in water, and it is the opinion of the writer that different sizes should be treated differently, to get the best results. This would make the plant more complicated and expensive.

The Campbell, Stewart and Robinson-Ramsay as worked out systems are similar. The coal is first washed then sized afterward.

STEWART:- The Stewart washer has two peculiarities. They are jig for washing all sizes together, and an attempt to separate the fine size by dragging the washed coal over a perforated plate. This plan for separation is not entirely successful as the conveyor is up hill to get the coal out of the sludge tank, and the conveyor flights too wide. This causes the coal to pile up in such a manner that it cannot all reach the screening surface. For this reason the fine sizes are not properly screened out. The larger sizes are separated in the usual way by revolving screen.

ROBINSON-RAMSAY:- The Robinson-Ramsay washer consists of an inverted cone into which the coal is discharged. Water is supplied through an opening in the bottom. The whole mass is kept stirred up by a set of arms that extend down into the water. The action of the water rising in the bottom is to lift the coal and float it over the side of the cone, while the impurities settle in the bottom to be removed through valves provided for that purpose. Carried over with the water is a considerable amount of fine impurities that do not settle readily. This and very fine coal is carried through the drainage screens with the water and to the sludge tank, where the fine impurities settle and are discharged, and the coal is carried with the water back to the washer.

LUHRIG:- The essential feature in the Luhrig washer, is the sizing of the coal, while yet dry, before washing. In this condition it is much more thoroughly separated. Each size is washed separately and discharged over a drying screen into the storage bins. The two finer sizes are washed together and separated afterward by washing through a small revolving screen. To thoroughly separate fine coal it must be bone dry or have water enough with it to flush it through the meshes of the screen.

All washeries are more or less complicated, require a large amount of water and are somewhat difficult to keep going in winter weather. The water is usually used over and over from a tank in the washer. This makes it easy to keep from freezing by diverting some of the exhaust steam to heat the water. It seems that the possibilities lying in this simple remedy are not appreciated by most operators. The waste of water is made up from some outside source. The water must be occasionally changed, as it becomes saturated with clay and dissolved salts. About one ton of water is required to wash one ton of coal. Fig 13 shows a Luhrig jig.

ELEVATORS:- Elevators usually consist of sprocket wheels over which run ordinary malleable iron link belt, or chains of special form, as there is always wear, and sometimes accidents it is desirable as far as possible to have several wheels alike. This minimizes the amount of repair stock necessary. Elevators should be preferably vertical but if inclined must have wheels or cast iron sliding blocks traveling on iron ways. Such ways should be 1/4" thick. The chain will depend on the work to be done but should not be called on to carry more than half the amount given in catalogs. Double chain elevators with gravity discharge is probably as satisfactory as anything where it can be used.

Elevator speeds run from 125 to 250 feet per minute, depending on the size.

Buckets are made of steel on malleable iron. Number eight sheet steel is about as thin as should be used for mine work, $1/4$ " for large buckets. Sometimes perforated buckets are required to drain water out of the coal, $1/4$ " is small enough for practical purposes. A very small hole is expensive, and will rust or clog up so as to make it useless. Buckets are usually bolted to the chain, in which case the thread should be flattened so the nut cannot come loose.

CONVEYORS :- Inclined conveyors that act also as elevators can be operated up to an angle of 30° . These are chain cable or monobar type. When operated horizontally they will carry coal 45° to 60° ahead, when inclined 30° they will carry the coal nearly level. Probably the most satisfactory flight conveyor for coal is a single or double chain with a supporting bar and sliding blocks at each flight. Wrot iron angle bars are used for slides. Cable conveyors have the objection of stretching and getting out of pitch. Revolving screw conveyors if of cast iron are very satisfactory. They will carry coal to twice the height of the conveyor, conveying much more material than the displacement of the screw. Its operation is not hindered by being covered deep in coal screenings. A nice speed is 200 ft per minute for the circumference. The pitch is usually about equal to the diameter.

PUMPS:- Pumps used for handling water for washers, are usually centrifugals. They are very satisfactory, as the mud, coal and impurities do not interfere with its operation.

SCREENS;- Screens are made with wire cloth and perforated plates. The cloth rusts out much more readily than the plates and is otherwise not so satisfactory.

The pitch is usually 1" per foot and the circumferential speed 150 to 250 ft per minute. One point to be noted in construction is to arrange the supporting arms so they will not interfere with the discharge of coal into the screen.

TRANSMISSIONS:- Various kinds of transmissions are used, belt , chain and rope. Ordinary hemp rope drives are very satisfactory and are much used in washeries for the main drive from the engine. In wet places, where the speed is not too high and conditions are otherwise unfavorable for belts, sprocket chains are used with excellent satisfaction. For ordinary conditions ,rubber belts are frequently used.

PUMPING

CONDITIONS:- The conditions under which mine pumps have to operate are about as bad as they could well be, and expect good service from a machine . They are located a long distance from the power plant, in out of the way places where it is not possible to keep them clean, they are required to pump muddy, gritty and sometimes acidulous water, and receive poor, indifferent or even no attention. Added to these conditions, too frequently the operator to save investment, will buy a cheap undersized, underweight pump, designed for totally different service, and entirely unfitted for mine work and expect it to do business. This it does under protest for a while, and then _____.

They are perhaps installed in a roomy pump house, but more likely in a mud hole, set on poor foundations or none at all, connected up with long steam line with no trap, operated at variable speeds or allowed to run away and yet expected to do duty.

MATERIALS:- A mine pump should be made of good material, iron steel ,brass or bronze castings, with no outside unnecessary finish.

On account of liability to rust, no connecting parts other than bolts should be of wrought iron. The piston rod, piston or plunger should always be of brass or bronze and the water cylinder lined with the same. It may even be necessary for the whole water end to be bronze, and cases exist where it takes lead to withstand the acid.

Pumps are made with parts lined with wood to prevent acidulous water from coming into contact with and destroying the metal parts.

In wet mines with soft bottom it is customary to tamp up the haulage roads with cinders. This is a source of trouble if water is allowed to stand on the cinders and become acidulous.

RECIPROCATING PUMPS:- The majority of mine pumps are reciprocating single or duplex steam pumps. The question of whether single or duplex pumps are the better is one most usually settled by the whim of the operator. There are good points on both sides. One serious objection to any class of pumps, is to have a multitude of places where adjustments can be made. Machinery in general is usually properly adjusted when it comes from factory. Pumps in particular receive all sorts of adjustments at the hands of incompetent attendants as soon as put in use. Simplicity, fewness of parts, and those parts not easily tampered with, coupled with plenty of good material properly distributed, are cardinal virtues in a pump.

Single pumps tend to fewness of parts except in valve gear which is complicated, must of necessity always be well lubricated and is not always positive. It should be somewhat cheaper for the same capacity. Duplex pumps are possibly more generally used, are absolutely positive in operation, are less liable to derangements and are more easily fixed.

The steam end of any pump should be made of hard cast iron with ample provision for cushion at the end of the stroke, so that the

piston will not strike the head. An important feature not always found, is to make cylinder rings of proper shape or quite thin, so that they will fit and be steam tight.

Compounding ,while frequently used in the deep metal mines is very seldom used in coal mines especially of the west; pressure ordinarily carried would hardly warrent it.

The water end of a mining pump needs the greatest consideration. Nothing but an outside packed plunger pump, with brass or bronze plungers, should be used. The valves should be so located that it will take but a moments time to get at any one , and hand holes conveniently located for cleaning out . The kind of valves to be used will depend on the service. Medium of soft rubber for gritty water shallow depths, same backed up with metal plate for high lifts. Hard rubber valves for gritty water wear out rapidly. For very high lifts use metal valves. What is said here also applies to power driven pumps as well.

The one great objection to steam pumps is that they are very wasteful of steam. Their first cost compared with electric driven pumps keeps them in favor. They should always be installed with steam trap and separator.

ELECTRIC PUMPS:- There are a good many advantages in electrically driven pumps. They are very economical as compared with steam. They can be placed a long way from the source of power, with but little loss in transmission. They will not "run away" when out of water. Small machines may be placed on trucks and moved from place to place for temporary use. Electric pumps are of three types, piston, plunger and centrifugal. The same objection holds with piston pumps, as mentioned under the head of steam. Plunger pumps may be two or three cylinder.

The triplex is usually selected because of the evenness of crank effort and small pulsation given to the water. The duplex double acting with cranks set 90° apart is even more desirable in this respect, than the triplex single acting. In recent years high speed reciprocating pumps are used to some extent, connecting the motor directly to the crank shaft, the plungers being relatively small and operating at higher than ordinary speeds. A mechanical efficiency of about 93 per cent has been obtained with this class of pumps.

CENTRIFUGAL PUMPS:- The great simplicity of centrifugal pumps is being to bring them into favor. The objection to very high speeds necessary for high lifts has been overcome by the multistage type which puts two or more pumps on the same shaft, the water going through the whole series before being discharged. They are made of bronze or cast iron as required, and have only two journals where there is any possible wear. The great advantage over other styles of pumps is the lack of valves and the ability to handle anything that will pass through the machine. A foot valve must be put on the suction pipe or hose to hold the priming water when starting. On some pumps, provision is made for priming.

A centrifugal pump direct connected to electric motor makes an ideal equipment which must certainly grow in favor. The single centrifugal mounted on a truck with hose and motor, will do more work with less trouble and energy and at much cheaper first cost than the cumbersome and complicated triplex pump now built for that purpose. The general use of truck pumps, is to be shifted from one part of the mine to another, for unwatering rooms and entry faces and delivering the water to pipe or ditch where it will flow to some stationary pump and there be pumped to the surface.

GASOLINE PUMPS:- There are situations far removed from any source of power, and when the amount of water to be pumped is not great enough to justify the installation of a steam or electric plant. In cases of this kind the gasoline driven pump has a very extended and successful use. There is ofcourse an objection to the use or storage of gasoline in underground workings, and requires very great care in handling it and in carrying open lights around where it is used. There are kerosene engines that answer the purpose equally as well as gasoline. Because kerosene is not volitile at ordinary temperatures, the same objections do not hold against it.

VENTILATION:- It does not seem to be commonly known , but it is nevertheless a fact, that a good fan and ventilating system will pump an immense quantity of water out of a mine. In summertime the atmosphere is usually dry, and will therefore take up a large quantity of water. In winter time ,the air becoming warmer when it is taken into the mine, will hold more water and therefore will absorb large quantities of water. The result is very noticable in mines where a large volume of air passes through the entries. The amount of water which may be taken out of a mine with the air may be estimated as follows;

Air at 60 degrees Farenheit will hold when saturated about 0.012# for each 12.5 cu. Ft of air. This is about the temperature in a mine. At 30°F. it will hold about 0.004#. In summer time it is safe to assume the air to be fairly dry at ordinary temperatures. The following formula will then give the approximate weight of water absorbed by the air per minute. $W = \frac{C \times 0.008}{12.5}$ in which W is weight of water removed in pounds and C is the cubic feet of air passed per minute. If this much water is absorbed, the conditions must be favorable so the air may become saturated. The air ways must be of considerable length and the moisture must be there to be absorbed.

POWER PLANT

BOILERS:- The types of boilers generally used for mining plants are of the return tubular type, on account of cheapness and economy. The first cost unit for unit is cheaper than any other type of boilers and when properly installed is about as economical as any and practically as safe. The tubes or flues expanded and riveted in at both ends form substantial bracing or staying for the ends which are flat surfaces, and the sheets above the water line can be properly stayed without much trouble.

CLEANING:- There should be installed one boiler in excess of the capacity required to provide for cleaning, inspection, and repairing of any one boiler without interfering with the operation of the mine. Cleaning the flues should be done daily. A good practice is to clean the flues as often as the fires are cleaned. Where compressed air is available it will give better results than steam for cleaning flues.

Cleaning the boilers internally should not be put off longer than two weeks, this however depends upon the kind of water used or in other words depends upon the amount of scale forming substances that may be in solution. The more mineral matter there is in the water, the more attention the boiler will require. This is because the scale forming substance when first deposited on the boiler shell is soft and when given attention at this period may be easily removed but when it is allowed to remain, and more and more scales collect, it becomes hard and can be removed only with a hammer or sharp tool.

Scale forming waters are so varied in their analysis and their proper treatment requires such an intimate knowledge of chemistry that it is not advisable to enter into a discussion of the proposition here. It may, however, be well to state that there are various

processes on the market for treating water both before and after it has been fed into the boiler. These may have more or less merit depending on circumstances. It is a matter that if entered into, must receive most careful attention, giving consideration to both chemical and mechanical means.

REPAIRING :- With one extra boiler installed , the necessary repairing as advised by the inspector, when boilers are insured, may be put in place while the boiler is down for cleaning. If there is no regular inspector the necessary repairs must be left to the judgement of the man in charge. If boilers have the proper attention at the proper time the cost for repairs will be small.

FUELS:- The fuel used at the average mine plant is usually the finer grades of coal. To accomplish good results from this kind of fuel there must first be installed suitable grates for the small sizes of coal; second to properly consume this kind of coal requires a great deal of air to be supplied to the furnace either by a blower or tall smoke stacks. The former produces the most satisfactory results. These blowers are of two types, steam blower and fan, both having their advantages and disadvantages. They discharge in various places, under the grate, in the bridge wall, or in the smoke box, the location depending upon the kind of blower used and the conditions. Fans are the more economical.

The finer sizes of coal pack down in the furnace so compactly, that it is difficult with natural draft to get the pressure required to get the air through the grates. The finer sizes of coal do not usually have as great heating value per pound as coarser coal, and for that reason the fuel bed must be thicker to get the same results, this aggravates the case, and makes it more necessary to use blowers.

HOISTING ENGINE:- One of the most important elements in a mining plant is the hoisting engine. The output of the mine depends on its design, stability and reliability. The safety of the men depends on the ability of the engineer to make it respond positively to his wishes.

TYPES:- The type of the hoisting engine depends upon several different things, among which are, the depth to coal, the output required, size of shaft, number of hoistways etc. Single cylinder engines are used but very frequently. Double cylinder engines are used for all the regular work of mining and may be divided into the following classes; geared, and direct motion, or by the character of the drum, as straight, conical, camel back and Koepe reel for flat rope, used only in deep metal mines. Each of these have a field of their own to which they are best adapted.

The geared engine is most suited for shallow mines and small output per day.

The direct acting engine is most suited for deep mines and those of large output per day. There is however a dividing line between the two types in which either one will give equally good results. So it is largely a matter of personal choice as to which is used.

Geared engines under very favorable conditions should not be run at a speed of over 1200 feet per minute, for the circumference of drum. With clumsy cast gears and the rough work to which hoisting engines are subject, the speed should probably not exceed 900 feet per minute. If the average speed of hoisting is kept at about two thirds this maximum the average speed will not exceed 600 ft. per minute. This will allow the use of moderate sized drums and will keep the piston speed within the limits of good practice.

Hoisting speeds for direct acting engines should not be less

than 500 ft. per minute, and even at that ,steam economy cannot be expected on short hoists. They can readily be run at an average speed of about 1500 feet per minute, and the largest engines in deep shafts and large drums can be run as high as 2500 ft per minute.

SIZE OF ENGINE:- The first step in this problem is to determine the load to be raised. This is limited to the size of hoist ways. The general practice is that after the preliminary work has shown favorable conditions as to the thickness of coal etc, the shaft is then sunk and the dirt, rock, slate etc is hoisted with an ordinary portable engine arranged for the purpose, after this part of the mine is developed the size of car that can be hoisted out of the mine and that will pass through the underground entries, can be determined.

If these place no limit on the design, the load to be hoisted will depend upon the desired output per day. For example suppose an output of 2200 tons per 8 hour day is desired and the mine has two hoist ways, one car being hoisted while the other is lowered, is 250 feet deep, available hoisting time seven hours and the time required to hoist one load and change cars, one half minute, then 120 cars can be hoisted per hour or 840 per day. This would require cars of $2200 \div 840 = 2.5$ tons capacity, in order to handle the desired output . The the load at the bottom amounts to 5000# plus the weight of the rope. $1 \frac{5}{8}$ " rope @ 4.15# per ft.= 1057# for 250 feet.

The greatest weight to be hoisted will be when there is a load on one cage and no empty car on the other. In this case this load will be 1057 plus 5000 plus 2000= 8057 #, the weight of a pit car being 2000#. Weight of cages are not considered, as they balance each other.

The next step is to determine the size of the drum. In this case as the hoist is very short the drum will not need to be large. The smallest allowable size for a 1 5/8" rope as taken from table, is 6 1/2 feet.

Steam pressure is usually 80# at the boiler, and the average pressure in this class of engine about 35% of boiler pressure. In making calculations of this kind it has been the practice of the writer to use 60# as the M.E.P. in the cylinder. His rule for size of cylinders is $\frac{2 \times 60 \times a \times s}{3} = P D$ where P is total load D is diameter of drum, a is area of cylinder and s stroke. In any case a length of stroke or a diameter of cylinder is to be assumed in order to determine the other. A builder of engines in Illinois figures on a basis of the full power of one engine at the center of the stroke, using 60# M.E.P. An engine will hoist a load that it cannot start. One reason for having cylinders large is to be able to hoist if steam falls, also when self dumping cages are used some kinds are rather difficult to dump.

DRUMS:- In determining the type of drum to be used for hoisting work, the question as to whether a common cylindrical or conical drum shall or shall not be used, does not receive special attention in ordinary cases for various reasons.

The question here considered is what is known as balance hoisting, where the mine has two hoist ways, one cage descending while the other ascends. The simplest form of drum used is the cylindrical, inasmuch as it is the cheapest, easiest made and the lightest. When running it gives a uniform speed to the load coincident to that of the engine. One revolution of the drum gives the load the same amount of travel wherever it may happen to be. The disadvantage of the cylindrical drum is that the load on the engine is variable,

the maximum occurring at the beginning of the hoist and when the other cage is empty at the top , and the minimum occurring when these conditions are just reversed. This variation in load in shallow mines is of little importance. In deep mines it is overcome by the use of what is known as the tail rope. This rope is attached to the bottom of each cage and passes under a sheave wheel at the bottom of the shaft. This balances the rope in all positions of the cage.

The conical drum has two points in its favor. One is that the load on the engine may be nearly equalized throughout the entire hoist, and the other is that the starting of the load requires less effort on the engine.

The disadvantage is, that at the end of the hoist the speed is of necessity higher than the average, and comes at a time when a slowing up should occur in order that the cage may land properly, especially where the self dumping cages are used.

Some of the above mentioned disadvantages can be overcome by a combination of the cylindrical and the conical drums, ordinarily known as camel back drums. In this type the speed of the load is at its maximum near the middle of the hoist, the speed then decreases, and at the landing the rope is on the cylindrical part which is smaller, thus allowing the landing to be made slowly.

Camel back drums are usually made so short that there is only a little more room than one rope requires. As one rope unwinds, the other immediately winds into the same groove. Sometimes but a single rope is used, with one end connected to each cage. This merely winds across the drum, three or four complete wraps giving it the necessary grip on the drum to handle the loads.

It is manifestly impossible to lay down a general rule for determining the choice of either type of drum.

The weight of the material, car, cage, or skip, the depth of shaft and the required output, must all be known before any definite statement can be made. There is no doubt however that the cylindrical drum is preferable in most instances, but this is not always the case. The choice of any style of drum, can only after a careful consideration of all the conditions having a bearing on the case, be determined. In any case the length of drum should be such that the rope in any part of the hoist will not make an angle with the sheave wheel greater than 6 degrees. Some State laws require a 4" flange on the ends of the drum.

THROTTLE:- The throttle of a hoisting engine is particularly important. It must always work freely and never stick. On account of the necessity of moving the engine slowly at times it is desirable to have the throttle move a very small amount, when just opening, with a considerable movement of the lever. Many of the later types of engines have the steam connections below the floor. When so installed there should be a steam trap to keep the pipes free from water. There has been many cases of throttle being broken by water hammer.

REVERSE GEAR:- The reverse gear must be easy to operate, the links free but not loose, and properly counterweighted. The valves should be wholly or partly balanced so that if necessary the engine may be reversed under steam. Steam reverse gears are a necessity on very large engines, but they have only recently been introduced on the smaller sizes of engines. Engineers as a rule prefer the hand reverse where it operates easily.

BRAKE:- An ordinary band brake consists of a strap of iron lined with wood blocks. This type is most frequently used and is operated on the smaller engines by foot or hand lever.

Intermediate and large sizes of engines have steam and hand brakes. The brakes should be strong enough to hold a loaded car or skip. For ordinary work they are not used, but in emergency they should be able to fulfill the demand.

SAFETY APPLIANCES:- There are supplied with some engines, safety devices to automatically stop the engine from over winding in case of accident or carelessness. There may be successful devices but the writer has not seen them. The wrong principle is involved, when it is necessary for the engine to run to its ordinary stopping point before the safety can begin to act.

LUBRICATION:- All parts of the hoisting engine subject to friction of any kind should be well provided for some means of lubrication. The surfaces subject to the most wear are often provided with what is known as power oilers, a pump which is operated by some moving part of the engine. Oil from the pump is delivered to the surfaces needing most attention. These oilers have the advantage over the ordinary oil cups, as when the engine stops the oil stops and when the engine starts the oil is forced to the proper place. Other places that cannot be conveniently lubricated with the power oiler, should be provided with oil cups of sufficient size to lubricate the part in subject for one day, in order that the engineer when on duty will not have to stop and delay hoisting to fill oil cups.

ELECTRICAL POWER:-

45

Electrical power is rapidly ^{coming} to the front

in mining operations. The economy and flexibility to be attained is far in advance of what can be obtained by any other method of power distribution. It is available at the same time for haulage, mining, pumping and lighting underground, and for power service on the surface.

It has advantages that are especially note worthy. The flexible conductors are quickly put up, and cable may be attached at any point to operate a machine, a distance away from the fixed lines; this too can be done very quickly in case of necessity. Copper wire always has a good scrap value, which iron pipe does not. Used for power on the surface it is better than steam distribution for any auxilary work. A motor can be enclosed in a very small place, and no expensive foundation is required. The wires do not freeze up and burst. Everthing is safe in the coldest weather.

Engines for this class of work are installed just in accordance with the fuel economy desired. In any case they must possess two qualifications; ability to withstand sudden and great variation of load without being pounded to pieces, and ability to hold up on long continuous runs. Large bearings, reliable continuous lubrication, proper balancing of reciprocating parts, good weight, and good workmanship and materials, will keep it going.

Generators are usually 250 volt direct current, either belted or direct connected. There are instances where the distance is so great that this voltage is too low, and where alternating current is used in connection with rotary transformers. There is at least one plant where double current generators are used, delivering 275 volt direct current and 169 volt three phase alternating current.

All standard makes of generators of recent make are good machines. A properly built generator will stand more hard usage than most engines of the same rated power. The allowable temperature rise is so small that it takes years of use to materially injure the insulation. Possibly one of the greatest difficulties that will be experienced will be the carbonization of dirt and oil, causing leaks and short circuits. This is not at all likely to occur where a machine is kept clean.

Switchboards should in no instance be of wood, either marble or slate properly connected up with standard instruments. Each machine should be protected by a circuit breaker, which should be so set as to properly protect the machine. Although one side of the machine is grounded in the mine, there should be a ground detector on both sides of the circuit so everything else can be tested out. Unless the lines are placed in conduits and under ground, lightning arresters must be provided, placed on the outside of the power house, and grounded with heavy wire. Kicking coils should be placed between the arresters as a further protection to the generators.

Wiring for mine work presents no especial features above ground. It is not usually well enough done. Lead covered cables are used to lead from power house down the shaft, where the lines are connected by single pole switches to trolley and rail. These are fastened to the shaft timbers at intervals of 10 feet by clamps that will not break or injure the lead covering. The weight however is carried by looping the cable around a large smooth grooved block at the top of the shaft so that the copper is brought into tension. The trolley is carried by mine hangers, which are somewhat similar to street railway trolley hangers, except they are made to bolt to overhead timbers or blocks. There are two ways in which they are

put up . Where poor roof exists, crossbars are used. In good roof holes are drilled ,about 8 inches deep and wooden plugs driven in, to which the hangers are bolted by lag screws. In rock roof regular expansion bolts are used. The trolley should be clear of coal, but dry coal is very poor conductor, and accidental contact will do no harm. Hangers are set about 30 feet apart on straight lines and 5 feet on curves. The trolley should be not only outside the line of the rail, but outside the line of the car body also, to provide against accidents.

AIR PLANT:- Not withstanding the fact that ordinary air plants have a much lower efficiency than electric plants, there are places where it is advisable to install them. Punch machines are better in some locations for mining than chain machines, and as there is to date no successful electric puncher, that calls for air. Very gaseous mines do not admit of electric apparatus, and here again air is used. While it is possible to install a plant of much higher than ordinary efficiency, the means that are necessary to attain the results involve such expensive machinery, and reheating apparatus, that is impractical in a mine, that the cheaper and less efficient plants are usually installed.

Single stage compressors except in small sizes are now little used. For ordinary work two stage type with intercooler is used in most installations. Few plants add the refinement of simple Corliss engines, much less compound. Air,unlike electricity, does not lend itself so readily to operating haulage and mining, as two separate compressors are required on account of two pressures being required. Ordinary mining machinery is operated at 80 to 100 # pressure, while 600 to 800# is required for haulage. This high pressure requires a three or four stage compressor with intercoolers.

Not enough attention is usually given to securing pure and dustless air, and more attention to this point will save repairs, and perhaps explosions.

Ordinary pressures require ordinary pipe for mains. High pressure requires double strength pipe and special recessed couplings caulked with copper. Care must be exercised in the installation in the mine, to have all pipe solid and well supported so as to have little chance to be injured by falls.

Receivers are mere cylindrical shells with dished heads. They serve the purpose of equalizing the pressure and allowing moisture to collect, to be drawn off. There is a pressure equalizing system that is shown in Fig 17 which explains itself. It is of very doubtful utility unless there be reason for having absolutely uniform pressure.

Lubrication of air compressors requires more than passing mention. The use of low grade low flash oil is responsible for disastrous explosions. The high temperatures generated in the compression cylinders carbonizes the oil and dust and after a while the conditions of dust, oil vapor and carbon gets right and an explosion follows. There is a certain kerosene oil engine on the market in which the vaporizing of the oil is accomplished by a black hot surface, and the ignition by the heat from this surface, together with an initial compression of 90#.

The greatest good thing to be said of compressed air, is that reheating pays handsome returns on the fuel invested, equivalent to a horse power for each pound of coal used. There are three methods of reheating, dry, moisture, natural. A dry heater is a sort of stove, the air passes through pipes or receptacles exposing large surfaces to the fire.

The wet reheater consists of a tank of heated water into which the air is forced, and liberated below the surface. Rising through the water the air absorbs both heat and moisture. The moisture is a possible advantage in some ways in the cylinder of the machine using the air. Natural reheaters, suggest the absorption from direct contact with the air or with water.

CAGES and ROPES

KINDS:- Cages are built plain and self dumping. Plain cages have stationary bottom in which the car stands. This is provided with means to keep the car from moving while it is being hoisted. The object of a self dumping cage is to provide a means for dumping the coal from the car, without involving the time and labor necessary to take it off the cage, dump by hand, and replace it. There are a number of makes working on somewhat different plans. The idea involved in most cases being to make the cage bottom turn about a point, about three feet below the rail, at which point it is hinged to the frame of the cage. The principle is shown in Fig 18. Of the various cages, the Bond is more satisfactory than most others. It has the advantage of being easy to dump and of being absolutely safe from dumping when it is in the shaft.

In any self dumping cage the "keeper" or device that holds the car on the cage must be positive in action, very strongly built and hold the car securely while being dumped. The keeper is usually made automatic in action at the bottom of the shaft, so that as the cage lands it opens and as the cage lifts it closes.

The rails on the cage have a hollowed out place where one set of wheels rest. This is to cause the car to stop in the right place. This is made to fit the curve of the wheels, and is 1/4 inch deep.

Cages used for hoisting men are required by law to have hoods of boiler steel, and to be equipped with some sort of safety device to prevent the cages from falling if the rope should be broken. There are two methods in common use. One consists of a pair of eccentrics with notched faces, at each side of the cage. These are keyed to two shafts^{by}, which they are made to operate. In event of the rope breaking a spring clamps the eccentrics to the guides, the weight of the descending cage tightens them, and they sustain the weight. The other method is a pair of sharp steel bars one at either side of the cage. These are forced out and into the wooden guides in case of accident. This safety works in the same plane with the two guides, and when properly built are very satisfactory. All safeties are supposed to come into action immediately and not allow the cage to acquire any material falling velocity.

ROPES:- Hoisting ropes are usually six strands with hemp center 19 wires to a strand. Each manufacturer makes several brands. The stronger ropes are made of higher carbon steel, and are therefore harder and will stand less bending than softer ropes. The tables in makers catalogs give the minimum size sheave suitable for various sizes of each grade of rope. It will be noted that the hard steel ropes require sheaves about twice the diameter of the soft steel requirements. Another point to be noted is the very large apparent factor of safety used. This is because of the strains set up by reason of bending around the sheaves. A very interesting discussion of this matter with tables will be found on page 318 vol 48 of the Engineering News.

The fastenings on the ends of the rope are as important as any other point. At the engine drum the usual practice is to make three full wraps around the drum then through a hole in the drum, wrap the rope

around the engine shaft, fold back on itself and clamp together with regular rope clamps. The hole in the drum should be rounded off so as not to bend the rope too sharply. The rope is fastened into the socket in the following manner; A few inches from the end of the rope it is wrapped with wire, and the extreme end untwisted and folded back on the rope. This enlarged end is pulled down into the socket, which has previously been slipped over the rope, and babbitt metal poured in to fill the socket up solid.

The connection between rope socket and cage is usually made with a clevis and pin.

DESIGN OF BOTTOM

The design of the bottom will depend on a great many conditions, but all with some bearing on safety to men and property, facilities for hauling coal, and the size of output required. The word "Bottom" here, is meant to include only such parts of the workings as are immediately surrounding the shaft. There are always two hoisting cages. There are two general plans for the bottom, one cages all the coal from one side and delivers all empties to the other. The other plan has one loaded and one empty track on each side. The two general ideas are shown in Figs 14 and 15.

STORAGE:- The output desired will have control over the amount of storage to be provided for loads and empties. As there are always delays in starting in the morning, and delays also occur through the day, there should be storage provision for at least 30 minutes hoisting capacity. On an eight hour basis this amounts to 6% of the daily output. The amount of room required will depend on the capacity and length of cars, and must be figured out from that data.

VENTILATION:- That part of the bottom connected with or leading to the air shaft should be so constructed that in case of accidents or explosions the ventilation would not be likely to be stopped or escape roads closed up. An escape way should be provided at a considerable distance from the main shaft, and leading to the air shaft.

ENTRIES:- The entries near the shaft must be wide enough for two tracks, and still leave room for passing between them. The space would preferably be about 5 ft between cars so a mule can turn around.

The top must be well timbered, not using any posts in the center unless it cannot be avoided. The laws usually provide for man holes at stated distances along haulage entries; these should always be made as they often afford a safe refuge in case of accidents.

They should not be as wide as a car, at least three feet deep , and white washed so as to call attention to them.

TRACKS:- The tracks in the bottom should be laid straight all joints provided with fish plates and four bolts, and tamped up solid and filled in to the level of the top ties. About 30 feet next to the shaft is taken up with a diamond or crossover switch. This part is floored solid with 3 inch plank so as to provide solid foundation to spike the short rails to. The switch points may be stationary where small cars are used, the same as room switches. The more modern plants use movable points, usually shifted by foot, Fig 16 shows styles of diamonds. They are sometimes built entirely of tee rails, and sometimes parts are made of cast iron. They are usually built of arcs of circles joined together without any tangent. The diamond part in the center should be made of straight rails. The radius of curve should not be less than 15 feet, while 25 feet on wide gauges is better.

GRADES:- A very important item in connection with bottom design is to get the grades right for handling the cars easily. Usually it is necessary to give some consideration to the natural dip of the coal, and definite decision on grades are usually left until the bottom is developed for some distance. Where circumstances will permit a grade of one to one and one half per cent should be made in favor of loads and empties. Two profiles are shown adapted to the two kinds of bottom. The grades given there are ordinarily satisfactory

CAGING:- The more modern mines have self dumping cages. Such cages should have keepers so made that they will automatically open on reaching the bottom. The output of the mine depends largely on the ability to get a car of coal started on the cage as soon as it

strikes bottom. To do this the car must be started before the cage comes in sight. To avoid all danger of cars running into the sump in case the cage stops before it does come in sight, an arrangement has been devised that keeps a large block across one rail of the road except at such time as the cage is on the bottom, or so close that the car cannot get into the sump.

CARS AND HAULAGE

The general design of cars , the material of which they are to be built and the kind of haulage used must depend on a great variety of conditions. Some general principles may be laid down.

CARS:- The time for making hoist , and size of cars are the determining factors for out put of mine. The size of car will largely depend on the working conditions of the mine. Thin seams of coal require low cars . There must be room enough between the top of car body and roof so the car can be loaded. The cars are usually chunked up 6" to 18" above the car body. Car bumpers are usually 6" shorter ^{than} shaft width, and the car body 6" shorter than bumpers at each end. Inside width from 3 ft to 4'-6" according to capacity required. The 6" of bumper on each end is necessary to give room for coupling without danger. The usual basis for figuring capacity, is to allow 50# per cubic foot.

Wooden cars are mostly used, they are probably longer lived in wet mines than steel cars. The bottoms which are extended to make bumpers, are 2-1/2" thick, sides 1 1/8" to 1 1/2" thick. The draw bar usually extends through the full length with pin and link or hook connections. The binder bars are about 2"x5/8", cars with doors that lift up at the end, hung in the center of the car, need a supporting bar at center or open end so the car cannot spread. Car wheels must

have chilled treads, run from 12" to 18" in diameter with 3" to 3 1/2" faces. Wheels may be bored or steel core used so no machine work is required. Axles square, with turned ends, or merely cut from round bar and turn in a rough cast iron box, size of axles run from 2" to 2 1/2" round or square. Wheels usually run loose on the axle.

The difficulty with wheels that run loose on the axle is wearing in such a way that they lean together at the bottom and get wobbly on the track. There have been some cars built in which one wheel is pressed or keyed to the axle, so that except on curves there is no wear in the bore of the wheel. This is the correct principle to work upon. The writer has not seen any of these cars running so as to observe actual results. A wooden car of ordinary design, but equipped in the way just described is shown in drawing # 19. Roller bearings have been tried with poor success on account of rusting and sliding till the roller is worn flat.

Doors are either hinged at the top or are hung by side wings, as shown in drawing # 19. The latter is nearly always used in connection with self dumping cages, while the former is used principally for cars that are pulled off the cage before being dumped.

Of couplings or hitchings there are several kinds in use. The simplest being a short chain welded into one end of the draw bar with a hook in the other end of the chain to hook into the draw bar of the next car. A form much used in the larger mines consists of a chain with clevis at either end, the clevis pin is so made that it cannot be lost. There are some others which have more or less merit

Steel cars seem to be coming into favor of late. They are probably entirely satisfactory in dry mines, but in wet mines it is a question if the thin plates will not rust out too soon to make it

advisable to use them.

The gauge of the wheels should be $1/4$ " less than the track gauge. The axles should be center to center two thirds the track gauge in order to run around the short curves.

MULES:- Haulage by mules is still the stand by method for short hauls in opening up mines and gathering from rooms. It becomes expensive on long hauls. The bottom is usually fire clay, and if not kept dry will be worked up into mud by the mules feet, and makes it difficult to keep the track up in good condition, besides making it very hard on the mules.

ROPE:- Rope haulage is done by two methods, endless and tail-rope. The endless , as the name implies makes a complete circuit at a speed approximating three or four miles per hour. The driving engine is usually located on top but may be put in the bottom. The rope is usually $3/4$ " in diameter. Cars are hitched on singly or in trips of 3 to 6 cars. With single cars there is usually no trip rider, but where several cars are in a trip, there is a boy rider. The rope may be equipped with gripping devices at stated intervals, or a clamp and hook is used which will grip the rope at any point. The rope is carried in the center of the track on wooden or iron rollers and around curves on a series of sheaves set close together on vertical axles. Tension of the rope is kept right by a take up in the slack side near the engine.

The tail rope system differs from the endless in several respects. The cars are always delivered to the bottom in trips of any number up to 25 or 30. The rope that pulls the load is usually $3/4$ " while the return or tail rope is usually smaller. The loaded rope is carried along the track in a manner similar to the endless rope, while the tail rope is carried overhead on rollers to the point where

trips are made up thence over a bull wheel (large sheave wheel) and returns along the track. The tail rope must be twice as long as the pulling rope.

A lamp is hung on the front end of the trip, the trip rider takes the rear car. If anything happens, he gets off and short circuits the bare signal wires that run along the rib of the entry and the engineer stops the trip.

The engine used for operating the tail rope system is made reversible and has two drums on the shaft operated by independent friction clutches. While one drum pulls the other is loose and unwinding.

Rope haulage has one advantage over any form of traction haulage, and that is in places where grades are very steep. The pulling power is vested in the engine only, and tractive force has nothing to do with the case. It is also cheaper to install and no more expensive for repairs. It however does not possess the flexibility of the traction motor, and in case of complete break down it would be hardly feasible to put mules on the main roads on account of the sheave wheels.

ELECTRIC:- There are three forms of electric locomotives used in mine work. They are traction, rack and friction. The friction arrangement consists of a wooden rail in the center of the track which is gripped by rollers driven by a vertically placed armature. This has not proven a success in practical use, but the other two forms have been brought into very successful practical use. The voltage used by all systems using direct current is practically the same, being from 220 to 250. This current while possibly sometimes fatal to mules, is not so to men under ordinary conditions of contact.

The trolley is located to one side of the track and the hangers held up by plugs driven into holes in the roof or by cross bars. If possible the trolley ought to be at least 18 inches outside the rail for safety. The ordinary figure 8 trolley wire is best to use, as it is easier to put it up well or to repair, than the round, the main thing is to straighten it out properly when taking it off the reel.

The position of the conductor in the rack system is such that it cannot be damaged by falls, nor can either men or mules ordinarily come into accidental contact with it.

The traction locomotive is built practically the same by different makers except as to detail. There is usually a single reduction gearing and rheostat control, with speeds forward and backward of 4 to 12 miles per hour. Some builders shrink steel tires on the wheels, others use plain cast iron drivers. One builder who makes both kinds, claims the coefficient of traction to be 20% with chilled wheels and 27% with steel tired wheels. Knowing the weight of locomotive and grades to contend with, the hauling capacity can be ascertained. The tracks for traction locomotive must be heavier than for rack or rope system. The proper weight of rail for traction electric locomotive is $10 + 2 T = W_t$ per yard, when T = weight of locomotive in tons.

The rack locomotive possess some distinct advantage over the traction locomotive. It was originated for the purpose of handling trains over a light rail track and on grades that a traction locomotive could not be economically operated over. The rack consists of a strip of flat bar steel with square holes punched at regular intervals through out its length. This third rail is fastened in a wooden support shown in cross section Fig 201. Plan of Standard switches is also shown. This third rail serves also to carry current.

This locomotive can be run over any track already constructed, as it does not weigh more than a car of coal. It can pull up any grade as the draw bar pull is dependent on the ability of the motor only, and not on the weight of locomotive or condition of tracks.

There is possibly less expense incurred by falls, but the third rail, although not exactly in the center of the track, interferes with the temporary use of mules, in case of break down of haulage plant.

There are conditions where one sort of a haulage plant will do better than another. A plant that will deliver coal to the bottom for the least cost per ton at one place, may not do so at another place. In an old mine with tracks already laid and entries fairly dry, the rack system is probably the cheapest. In a new plant with grades within 4 or 5 %, good roads and top, the ordinary traction locomotive will probably handle a larger output for less money.

PNEUMATIC:- There is yet one important haulage system to be considered. That is the compressed air locomotive. The system consists first of a three or four stage air compressor that will deliver air at 600 to 800 # per square inch, second a reservoir made of several hundred feet of 5 to 8" double strength wrought iron pipe and which serves also to reach to the various charging stations in the bottom, and third the locomotive itself which may use the air with or without reheating. This system finds its usefulness mainly in gaseous mines where an electric spark would not be permissible.

The compressor is a machine well worked out, the troubles in this case will be due to the very high pressures to be maintained and to the care necessary to keep the machine in economical working condition.

The pipe line or reservoir must be put together with very great care using special couplings and caulking all the joints.

The locomotive itself consists of a reversable running gear similar to that of a steam switching engine. Cylinders usually about 7"x14" and designed to work at about 140# pressure. The cylinders may or may not be ribbed for the absorption of heat from the atmosphere. And the air may or may not be reheated. Reheating is usually done by passing air through coils of pipe submerged in hot water. The storage reservoir is built to with stand 600 or 800# pressure. It usually consists of two long cylinders with dished heads. The length necessary to get sufficient storage is such as to make them cumbersome and they will not pass around curves in the same space that electric motors will take. The tanks are charged by heavy rubber hose with specially made couplings, the time consumed being about one minute. The air passes from the locomotive storage tanks through a reducing valve to a receiving tank where a pressure of about 140# is maintained. The efficiency of this sort of an arrangement is considerably less than the electric, unless a very good system of reheating is maintained. On the other hand the air motor is independent of any trolley and can be run any where the track is laid within the limit of distance from the charging station.

TRACKS:- Ecomomic haulage by animal or motive power is largely dependent on the condition of tracks. The rolling friction on ordinary mine tracks is about 35# per ton, which compared with that of railway cars is high. Bad conditions of track and cars may put it up to 50 or 60#. In order to make this a minimum, not only must the car be kept in good condition and the axles well oiled, but the tracks must be well built and kept in good condition.

For main haulage roads, steel tee rails are always used and

and should be laid straight, graded and provided with fish plates. Where no motor is used the weight will run from 16 to 20# per yard, with room rails 12 to 16#. In many places wooden room rails are used. They are even said to be successfully used without ties.

Tracks where mules are used are much more difficult to keep up than tracks where rope or motor haulage is used. This arises from the fact that the mules feet work up the clay between the ties into holes or mud, and the mud will not support the weight.

Tracks are usually 24" to 48" gauge -30" - 36" and 42" being the more common. Ties are all sizes of material from 3" x 5" to 6"x8" depending on the weight of rails. Rails spiked down by ordinary tee rail spikes of small size. The length of spike used being ordinarily about the same as the height of the rail.

SWITCHES:- Mine switches for motor haulage are usually split points, with a ground throw. For mule haulage and room switches the points are fixed open both ways, and the car"slewed" to whichever track the driver wishes it to go.

GATHERING:- Even in motor haulage systems, it has been usual to gather the coal from rooms and make it up into trains, with mules.

There are now on the market light electric locomotives which are used to run into rooms and pull single cars. The locomotive gets its current through a cable attached to trolley and rail, which is automatically wound or unwound on a reel as the locomotive travels.

TIMBERING

The whole question of timbering in the mine is one in which individual judgement of the pit boss or timberman must necessarily be used. There seems to be no set of methods, instructions or formula worked out as a guide for this kind of work, and if there were, the

Conditions in different mines vary so much that the individual judgement is absolutely essential. In a majority of mines there is not the least semblance of system to timbering, and many of the timbers themselves are so weak and flimsy as to have no real value.

It would seem possible to work out general formulae and set of general instructions that would be a valuable basis to work from, and would if followed out make mine work less dangerous.

The necessity for timbering does not always exist but usually does. It arises from the fact that the roof over the coal is not strong enough to stand and support the overburden. Lime stone or sand stone sometimes accurs immediately over the coal, and in that case very little timbering is required. Slate or shale always required timbering in wide places, but sometimes does not in entries. Conglomerate rocks or slates, with irregular seams running through in all directions is the worst form of roof, because it cannot be depended upon. When it falls it is usually without warning and what may appear safe in the morning, may not remain so for a half day.

Timbers are set for the purpose of preventing a roof from becoming weak, after a break has started it may be very difficult to hold or stop it.

BOTTOM:- Where timbering is necessary around the bottom of the shaft it is usual to use sawed timber. Timbers 10"x10", 12"x12" or even 12"x16" are set transversely across the entry, supported in notches cut in the coal, or by heavy posts set at the rib or side of the entry. These timbers are usually set about 3' to 6' apart and covered above with 2" or 3" plank lagging. Where it is desired to make a good job, whatever space may be between the lagging and the top will be filled in with any sort of waste material that may be at hand, so as to hold the top from starting.

Where the coal vein is not thick enough to allow clear head room of seven feet it is usual to take down enough of the top material, so there will be that much head room after the timbering is done. It is poor economy to have either height or width crowded. Accidents are much more expensive than a little extra room or extra cost of timbering.

CROSSBARS:- Cross bars are usually of rough round logs, from 8" to 20" in diameter, and of such length to span the space where used. They are used principally for entry work where the span is 8 to 16 feet. The material that is to be supported, is not usually very great, else timbers that are used would break more readily. The lines of pressure will form into an arch and be carried to the pillars, the essential condition being, to keep the center from falling out, or starting to give way. The writer is of the opinion that if wedges are driven above the cross bar so that it is brought into strain, the material to be supported will be in the form of a triangle whose base is the width of the entry, whose height is not more than one fourth the base, and with apex in the center of the entry. If this be so, let

W= weight of material per cubic ft.=120#.

Z= width of entry in inches.

Use the formula S.I.= M.C.

Consider the bar square, and as the timber is likely to be only partly seasoned, then

S= 2000

$$I = \frac{b d^3}{12} = \frac{d^4}{12}$$

$$\frac{2000 d^4}{12} = \frac{5 Z^3 d}{288 \times 2}$$

$$\frac{d^4}{d} = \frac{60 Z^3}{2000 \times 288 \times 2} = \frac{Z^3}{19200}$$

$$d = \frac{Z}{27} \text{ nearly.}$$

As cross bars are usually round, and the sap has not much strength we will consider the round bar as only equivalent to the strength of the square bar that could be cut from it. The side of the square is to the diameter of the circle as 5 to 7 nearly. Our formula becomes $d = \frac{7 Z}{5 \times 27} = \frac{Z}{20}$ nearly. That is a 10 foot entry would require the cross bars to be 6" in diameter at the small end if placed 4 ft center to center. This will not hold good where the overhead material is soft.

PROPS:- Props or posts are usually used for supporting the roof of rooms or other wide workings. The length varies with the thickness of the seam. The diameter, so far as the observation of the writer has noted, has not been made a function of its length, as it should be. About the nearest thing to a specification that has come under his notice, is that round props should be at least 5" in diameter at the small end inside the bark and for other shapes to have not less than 20 square inches of solid wood. With long props this diameter is too small. However with the growing scarcity of wood props are accepted that have very little value, crooks equal to the diameter, and small ends down to 3" being taken.

Props are set with or without cap under the bottom, and usually with a cap on top. The cap piece being a block of wood 4" to 8" wide 2" thick and 18" long. These are sometimes sharpened to a wedge shape so as to get the prop tight. With the careless way of setting a very small percent have the bearing squarely on the end. Another difficulty along this line occurs where miners set their own props.

Often the prop is too long, and as the miner uses the fewest possible number of tools, instead of sawing the end off square, he hacks it off with a dull ax. The result is such as to give the prop the least possible show to hold up a load. Props almost always fail by buckling, a thing naturally to be expected as the result of the method of setting them. It shows one of three things; the diameter too small for the length, the prop originally crooked, or the bearing on the ends not square. To properly calculate the size of a prop, is a rather more complicated process than for cross bars.

The action of the top in wide places may not be, and the writer believes is not the same as in a narrow place. It will depend also on the kind of material the overlying strata are composed of.

In very many places a certain number of feet in thickness will come down, after which the remainder will stand indefinitely. In cases of this kind after the thickness is known it is only necessary to figure on the weight to be supported over the area. In many places this material that is likely to fall would not break if the span were not so great, and in that case it is not necessary to support the whole weight of the mass, that unsupported, would fall, as it will act as a beam not strong enough to support its own weight.

It would seem that for each field the spacing and number of props will have to be worked out tentatively, and in opening up an entirely new field guess on the safe side until the opportunity offers to determine the conditions more exactly by experiment. The one thing to always keep in mind is, that if the top is to be held up with the minimum amount of timber, it must never be allowed to start to fail.

METHODS OF MINING

There are two general methods of mining, Longwall and Room and Pillar. There are modifications of these methods to suit conditions. The choice of method depends on what is best suited to get out the largest per cent of coal, with the greatest safety to the men.

LONGWALL :- Longwall as the name implies has a long working face, and that face perpendicular to the haulage ways leading to the shaft. There are two general methods of work, advancing and retreating. Advancing leaves a pillar of coal to support the shaft, then takes everything clean as it goes. The working faces are in a circle and the entries radiate, something like the spokes of a wheel. The top closes down on the bottom as the face advances, so the entries must be cut out from the solid material above the coal. Retreating, drives entries to the boundaries of the property, and takes out the coal coming back toward the shaft, so the entries do not have to be kept open after the coal is taken out.

The conditions favorable to longwall work are thin veins, and top that will break readily. Any amount of material above the coal that may have to be taken down to make working room is thrown back in the gob or worked out space to fill up the space. Props are set to be drawn later and reset, allowing the top to where they were to settle down.

Machines are used to a great extent for undercutting. There are several types but the rotating disc and the longwall chain machines seem to be best suited for this work. The longwall machine makes a continuous cut along the face of the working from one end to the other. There are two methods by which they are propelled as they make the cut. One kind of machine is on a truck which runs on a track laid near the face. The wheels of the truck are driven by the

power of the machine as it makes the cut. The other machine is propelled by a chain which is wound on a drum. The chain is fastened at the two ends or ~~one~~ only at one end as the case may be, by a jack set up against the roof. The drum is revolved by a worm gear connection of the motor. The depth of undercut in longwall mining depends on the thickness of the coal, and is not so great as in thick coal worked by the room and pillar methods. It will vary from 3 to 5 feet. The thickness of the kerf or cut with chain machines is about 4 1/2".

ROOM and PILLAR :- The room and pillar method is usually work in the thicker veins of coal, also where the top is hard and not easily broken or "brushed" down. Rooms are not usually "turned" off the main haulage entries, but usually off the side or "butt" entries. The reason for this is in case of a "squeeze" the main entries are to be protected as they cannot be damaged.

Main entries are usually 8' to 12' wide and high enough for mule to travel. If the coal is not high enough, the additional height is obtained by brushing the top. The entry is widened to provide for two tracks at passing branches. The State laws usually provide for man holes cut in the rib of haulage entries about every 60 feet, these are used as places of safety when cars are passing. Some companies make a practise of white washing these places so as to attract attention.

Side entries are usually the same width as main entries. They do not require refuge holes as the rooms provide that. There is a some what different method used in putting in passing branches on side entries. Instead of widening the entry it is usual to cut crosscuts through the room pillars and make the branch into a room, through three or four pillars and out at another room.

The rooms themselves vary in width and length, and thickness of pillar between them, according to thickness of coal, quality of roof and depth of coal below the surface. The width will run 18 to 40 feet according to the top. Pillars run from 6 to 20 feet according to depth below the surface, the crushing strength of the coal, and the quality of the bottom. The bottom may be so soft that large pillars may be needed to prevent it heaving and closing up roadways. Where conditions permit, it is cheaper to drive wide and long rooms as it cuts down the dead work. The profit does not come from entry or room turning work, but from work in the room itself.

Machines used for room undercutting are both chain and pick. The chain machines(electric or air) usually do the cutting on the end of the machine, that is, driving straight into the coal. The width of each cut being 3 to 4 feet, and the depth 5 1/2 to 7 feet. Some machines, the Sullivan for example, cut straight into the face at one side of the room, then across the face similar to longwall. Pick machines are driven by compressed air, and are used for two purposes, undercutting and shearing. The mining of the undercutter is about 18 inches high in front and 3 inches at the back. This allows more room for the coal to fall, than is the case with the chain machine, in consequence of which it makes a greater percentage of lump coal. Shearing machines make a vertical cut, either on one rib or in case of machines mounted on a truck, at the point in the room or entry where the track is laid. If the coal is undercut, the shots are so placed that the coal is shot down. If sheared then the coal is shot side ways.

The amount of work done by any machine is dependent on the skill and carefulness of the operator, and upon the coal itself. On entry work about four entries per day of eight hours.

The greater part of the time being consumed in moving from one place to another. The actual time consumed in making a single undercut with a "breast" chain machine being about 5 minutes, 10 minutes being required to move and set the machine for another undercut. The work an ordinary punch machine does is entirely in the skill of the operator.

Pick mining or hand mining in many places has come to be nothing more than "shooting off the solid". It involves only judgment in drilling the shot holes, and in proportioning the charge of powder so as to bring the coal down without shooting it to slack.

VENTILATION

A thorough discussion of this subject would involve more space than is possible to give here. The two objects to be attained by ventilation are the supply of fresh air to men and mules and the removal of inflammable or other dangerous gasses from workings. To attain this object the conditions in the mine must be kept good. Airways should be large if long, properly protected from danger of falls that would close them up, and should be as free from friction as possible. In Europe the gang ways or entries are arched over with brick. This reduces friction to a minimum, but is not done in this country. A series of experiments carried out by a French engineer resulted in the following determination for equivalent area:-

Arched brick lined	2.289
Rock(rough)	3.568
Timbered	4.380

AIR REQUIRED:- The amount of air required per minute per man or animal varies in different States. In Illinois it is 200 cubic feet for men and 600 cubic feet for animals. In Indiana it is just one half that amount. There is another factor worthy of consideration. In case of accidents it may be desirable to have large quantities of air, but more likely that high pressures will be required to handle normal amounts, caused by a partial closing up of entries. This point is then to be handled by selecting a fan capable of producing high pressures. The pressure necessary to supply a given amount of air is determined by the following formula;

$$p = \frac{K S V^2}{a}$$

in which p is the pressure per square foot, S the total square feet of rubbing surface exposed to the air, V the velocity of the air in feet per minute, a the area of the air way in square feet,

and K a coefficient whose value depends on the nature of the sides of the airway. There are a number of different values given for K by different authorities. The most generally accepted value for general practice has been .0000000217. Fairley gives a value of .000000001, but recent experiments made by Morgue show that even that is too high. His values average about as follows;

Straight normal sections rock	.000000005
" " " timbered	.000000008

These latter figures are more nearly in accord with every day practice in mines of the middle West.

FANS:- The more usual types of fans are the Guibal ,Robinson, Capell abd Sirocco. The Guibal or similar fans are the most simple consisting of plain radial straight or curved blades. They are usually of large diameter and slow speed. In this country they are usually used at mines that are not gaseous, and where high pressures are not necessary.

The Robinson and Capell fans are very similar. The main difference being that the Capell is usually installed in a brick or wooden fan house, while the Robinson is enclosed in a cast iron case. They are both of the high speed and high pressure type. They are both heavy and strong, built for high speeds when considerable power is required to drive them. They are suitable for gaseous mines, and mines where the workings are very extensive.

The Sirocco fan is a new type with several distinctive features that are not all easily explained. Fig 32 gives a sectional view, also the peculiar shape of the blades. These fans have a very high efficiency, due largely to the short radial length of the blades and their nearness to each other. There is little chance for wasteful eddy currents and the inlet opening is relatively very

large. The peculiar shape of the fan blades is claimed to give the highest air pressure possible.

BUILDINGS:- Fan buildings are usually of wood or brick. They are generally so built that the direction of the air may be reversed without making any change in the direction the fan turns. It is usually essential that the hoisting shaft shall be the up cast in winter to keep it from freezing. In summer time it is generally reversed.

POWER REQUIRED:- The horse power required to drive any fan doing a given amount of work is expressed by the very simple formula,
$$\text{H.P.} = \frac{p \cdot a \cdot v \cdot e}{33000}$$
 in which p is pressure per square foot, a the area of the airway, v the velocity of the air at the point measured and e the efficiency of the fan. The pressure is measured in inches of water gage. $p = 5.2 w$, where w is the water gage. The efficiency may be almost an figure but not likely to be more than 75%.

The various methods of driving are direct connected to engine or motor, belted to engine or motor. Guibal fans are usually direct connected and run at speeds varying from 20 to 100 R.P.M. The other types of fans are belted or direct connected to high speed engines or motors. For mine work they are very generally belted.

SYSTEMS:- There are three systems of distributing the air in the mine. They are the three entry and double entry with split air currents, and what may be termed a tandem system. The three entry system uses the two outside entries for fresh air and the center one for the return air. The double entry system with split air currents, is essentially the same as the three entry system, except that the air is driven down to the face of one entry and the same air returns through the adjoining entry. In the latter case the air has twice the chance to pick up gasses, as in the former.

Some State laws require air splits made often enough so that not more than 50 men are supplied with air from one split. In the series or tandem system all the air traverses the entire length of all the entries. There are several reasons why this is objectionable. The long airways make higher pressures and therefore greater power necessary to ventilate the mine. The whole of the gasses are carried through all the workings. An accident in any part of the mine affects the whole of it. This system is used in no up to date mine. Fig 23 - shows an ordinary double entry split system.

Over-casts are necessary in order to carry air across other airways. They are made above or below the entry to be crossed. It is not usual to make them below but conditions may be more favorable in dry mines that have a stone top. Ordinarily a groove is cut across the top of the entry to be crossed. Its size will depend on the amount of air it is to take care of. It is carefully timbered and boarded up tight. Tongue and grooved boards are often used.

Trap doors are used to close the opening between entries so as to preserve the ventilation. They are swung on hinges and made as closely fitting as possible and yet work freely. They are made to be operated by hand or automatically opened by the car as it approaches either side. Even more frequently they are hung to open freely both ways and are pushed open by the mule.

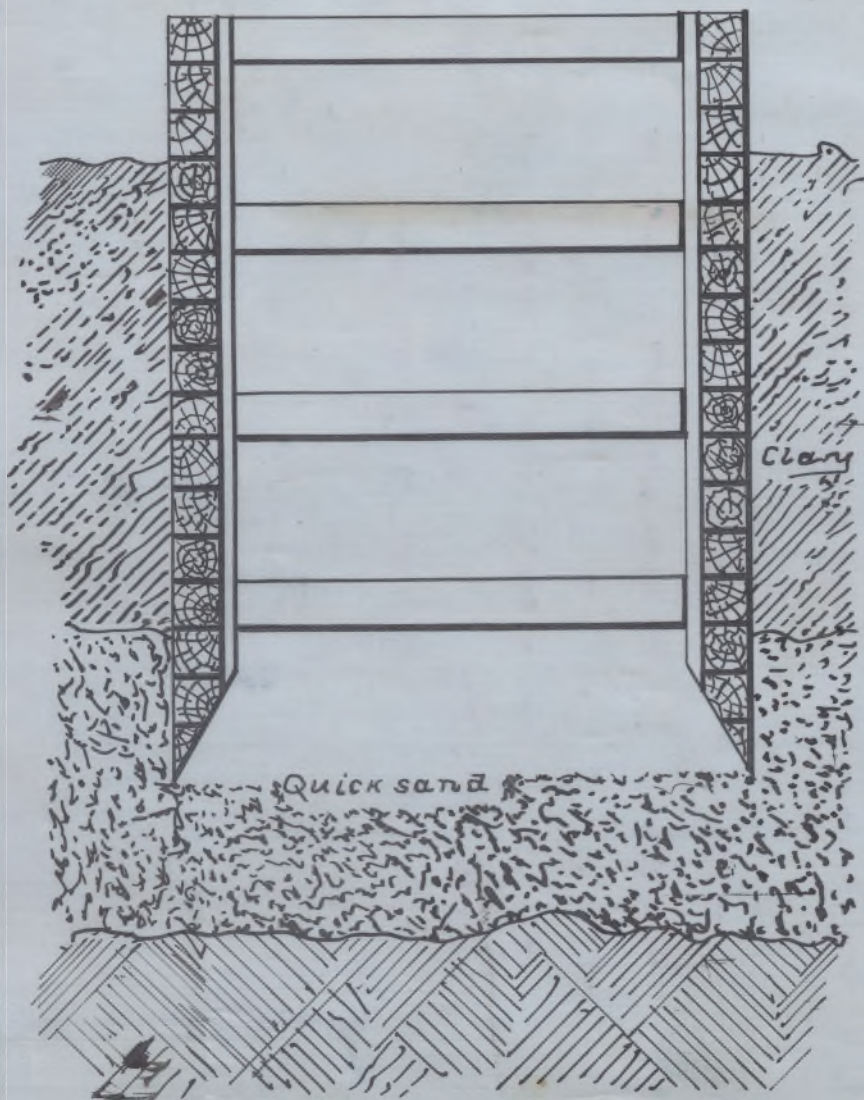


FIG. 3

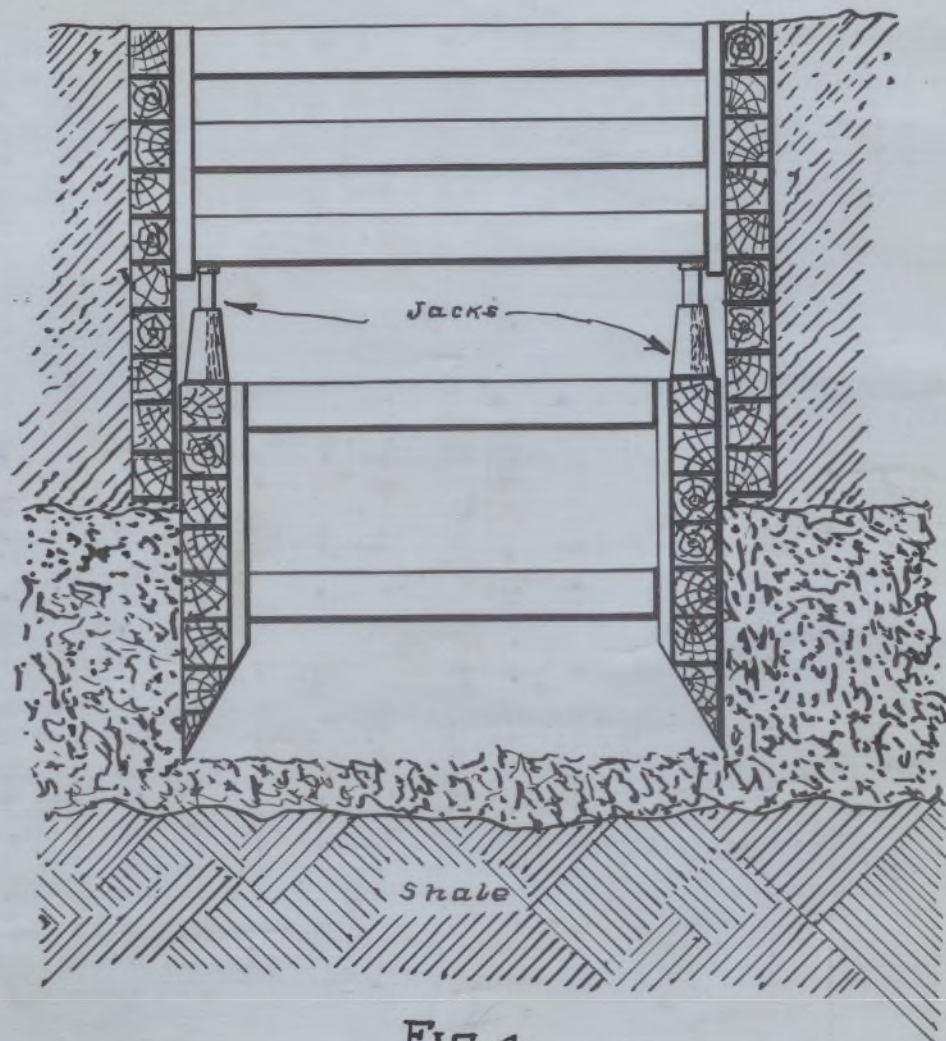
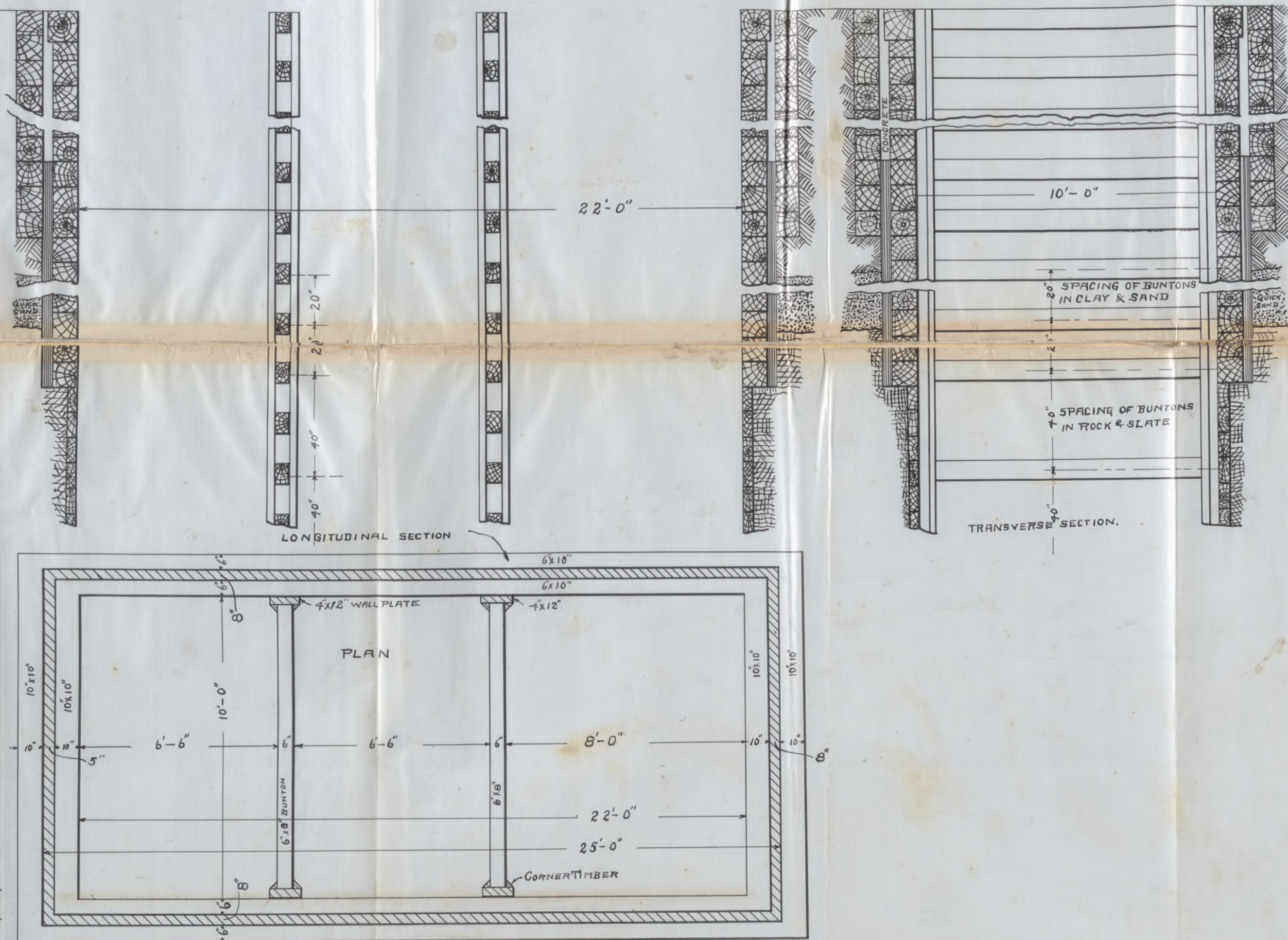


FIG. 4



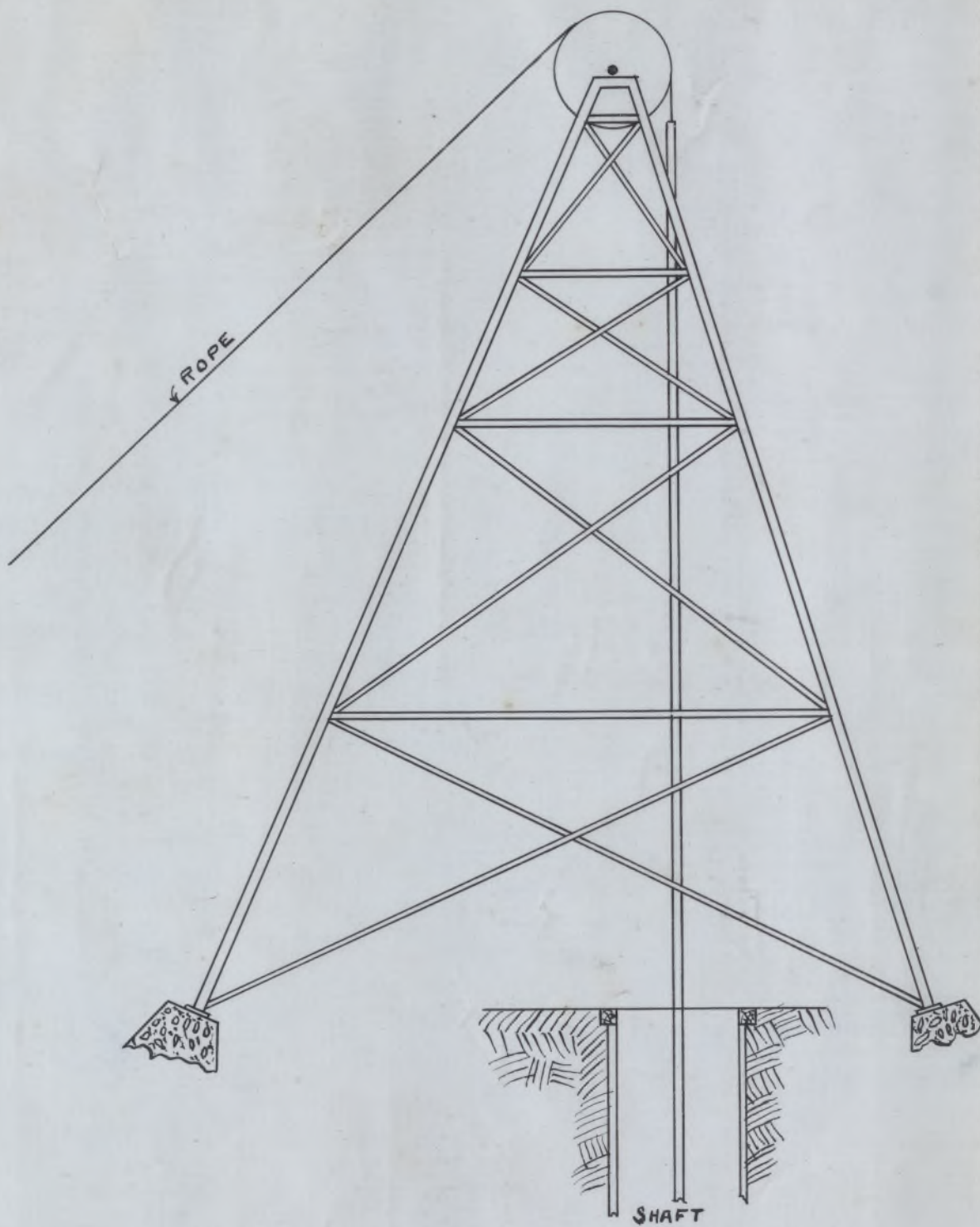


Fig. 9

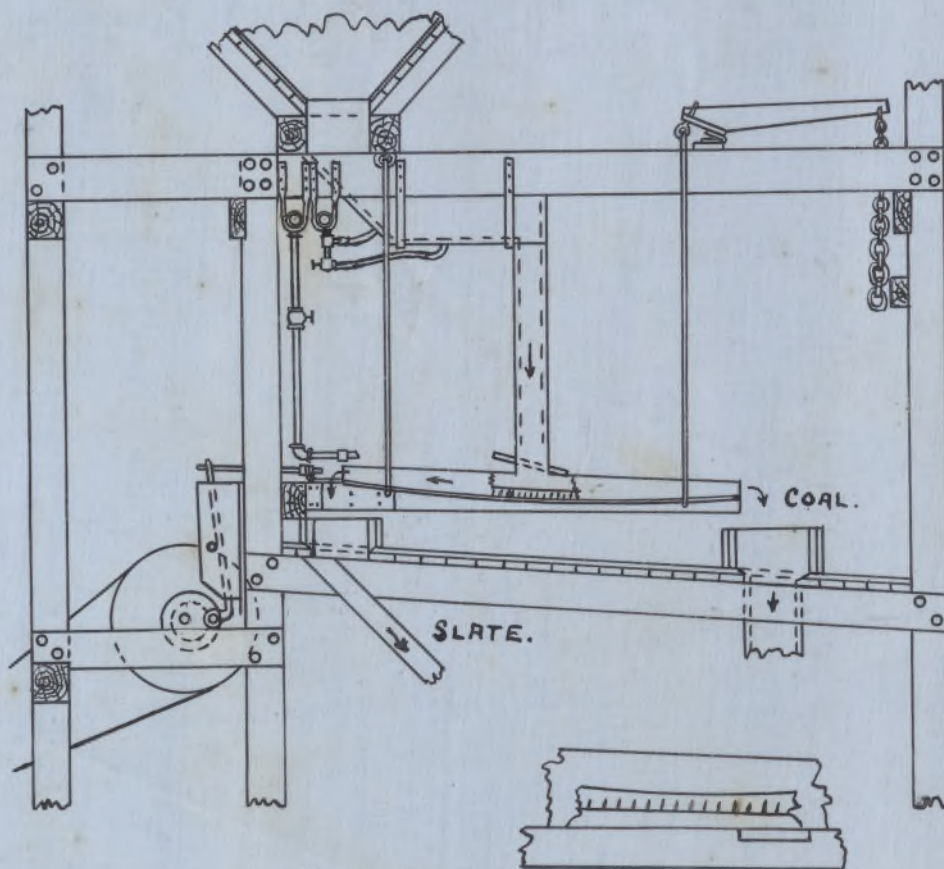
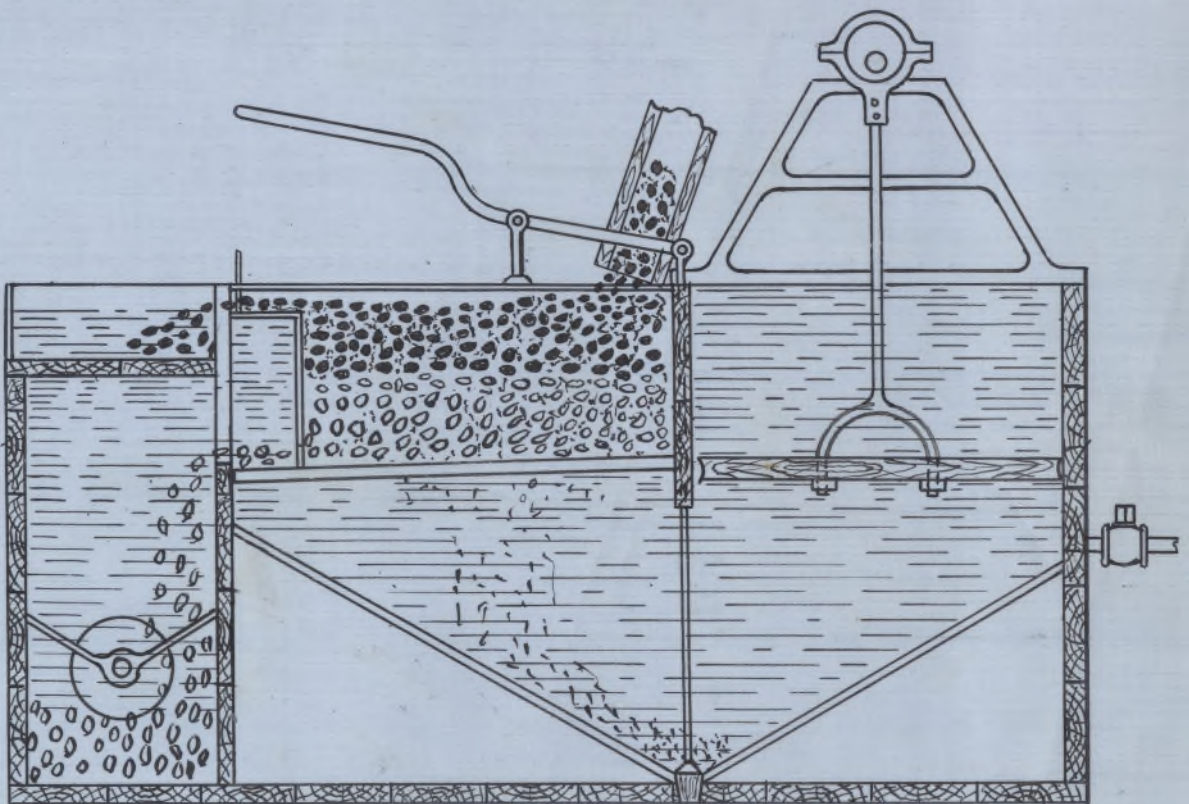


FIG. 12



LUHRIG JIG.

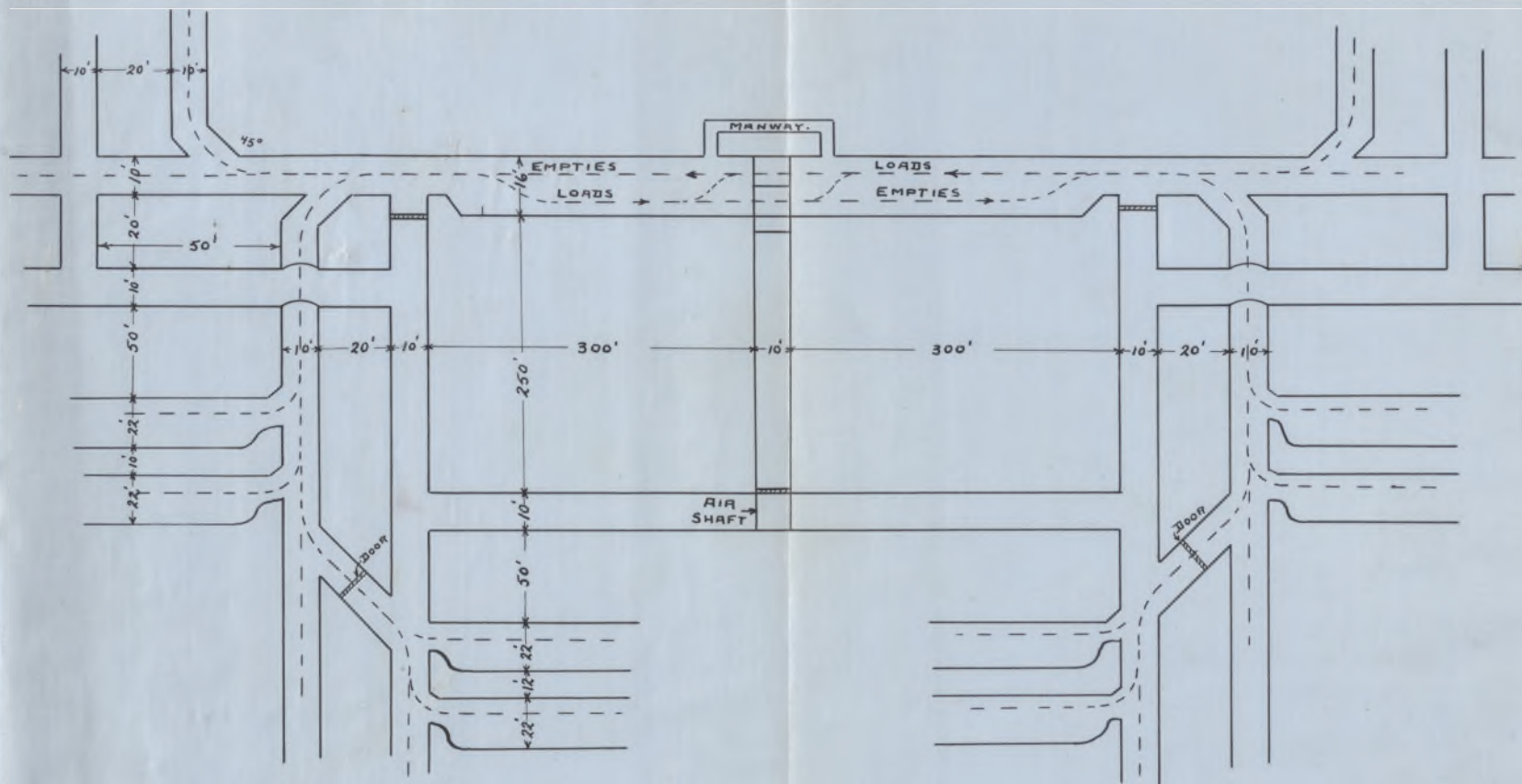
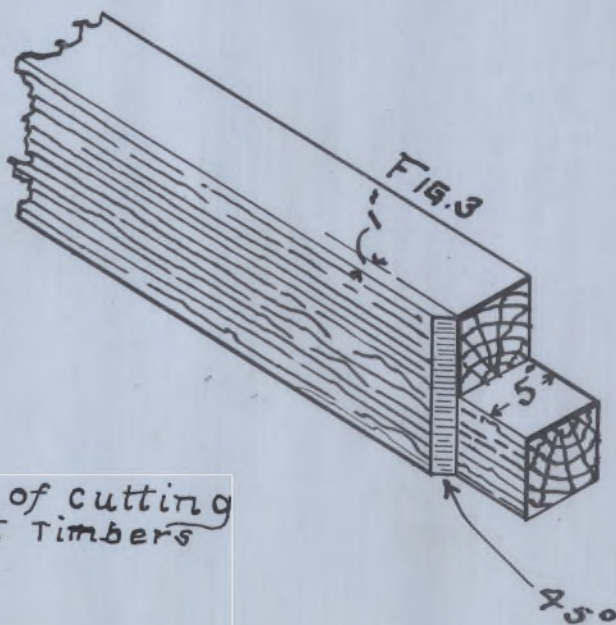
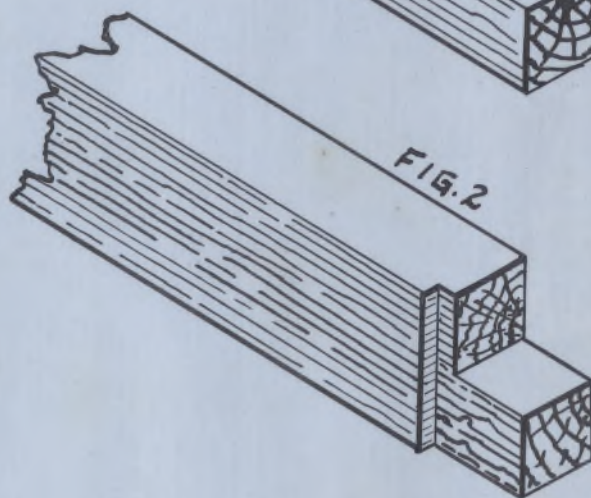
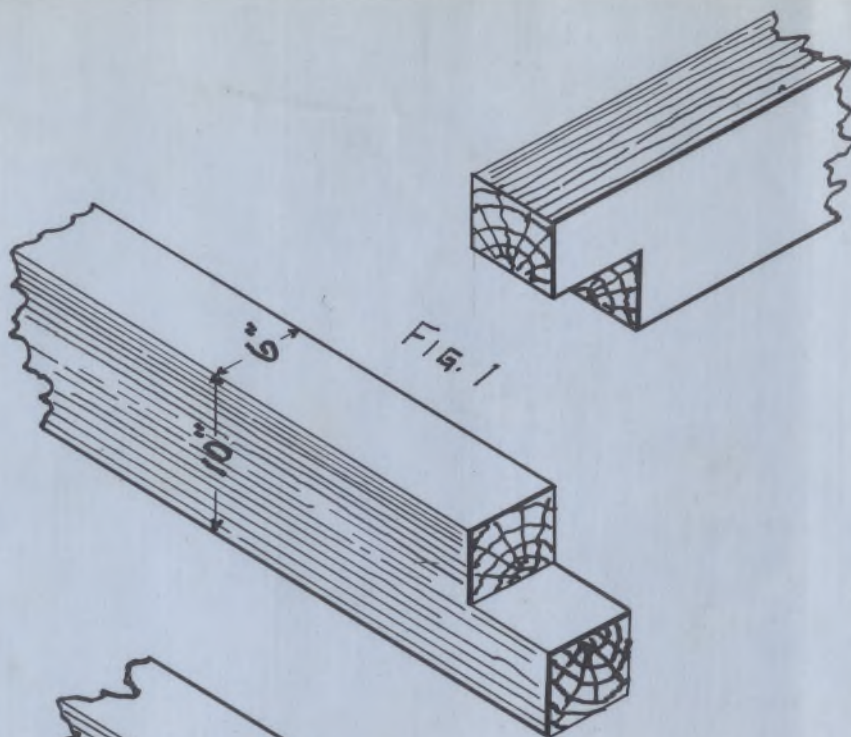


FIG. 15



Methods of cutting
Shaft Timbers

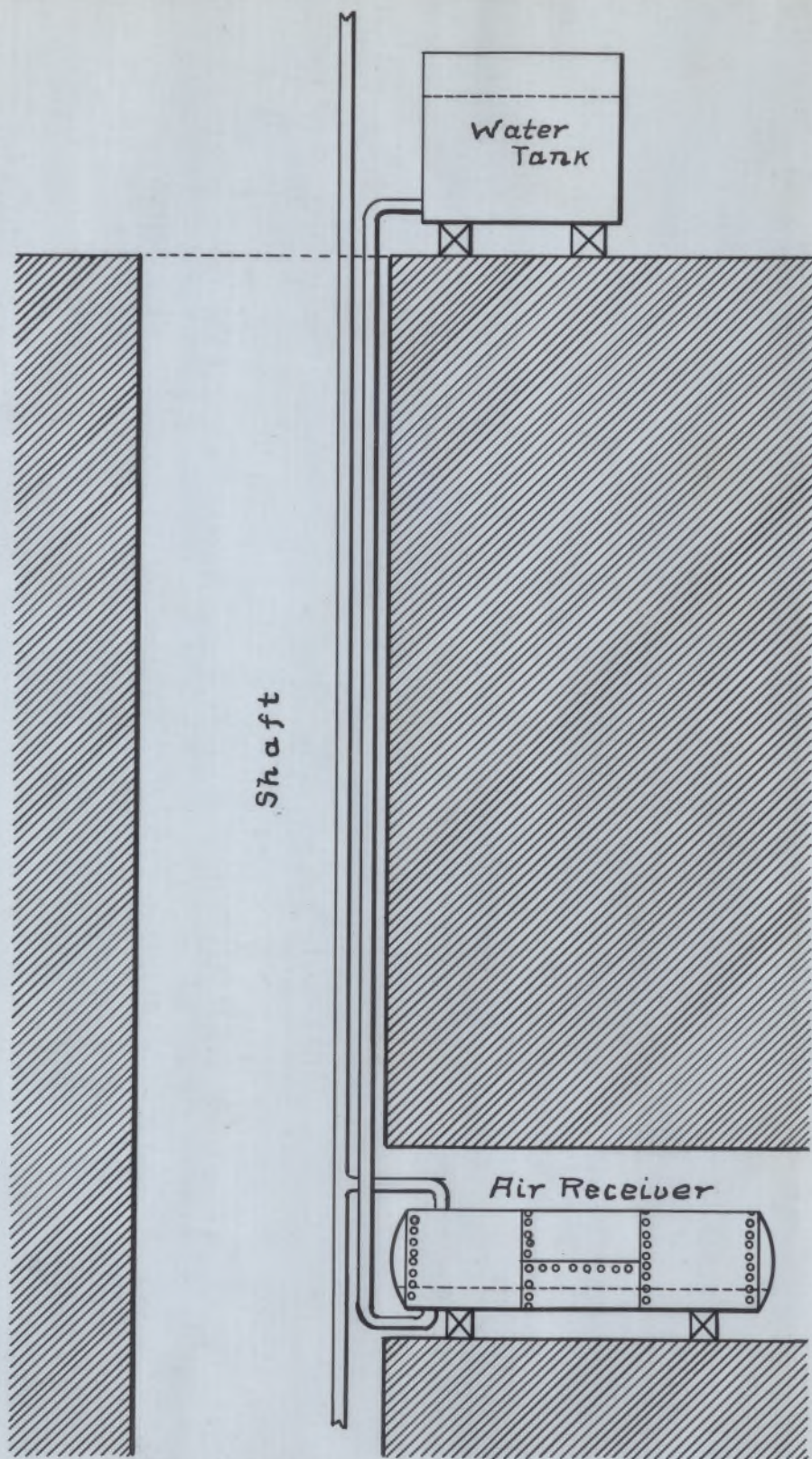
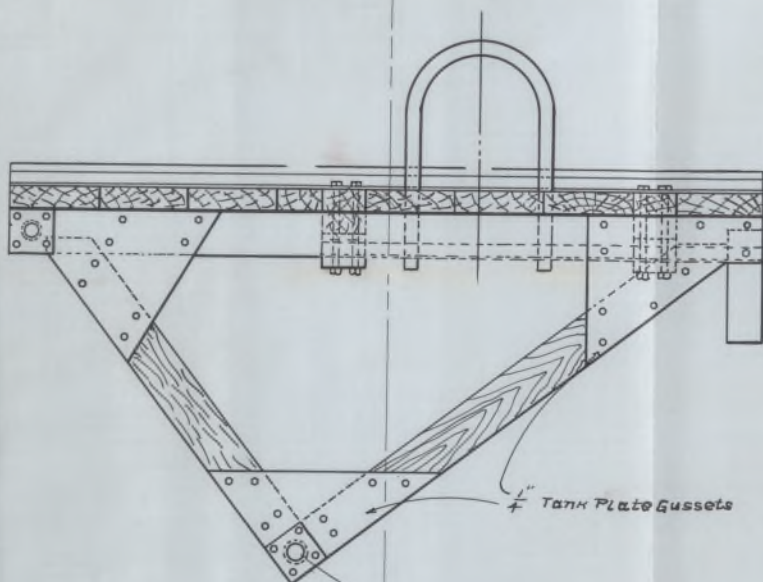
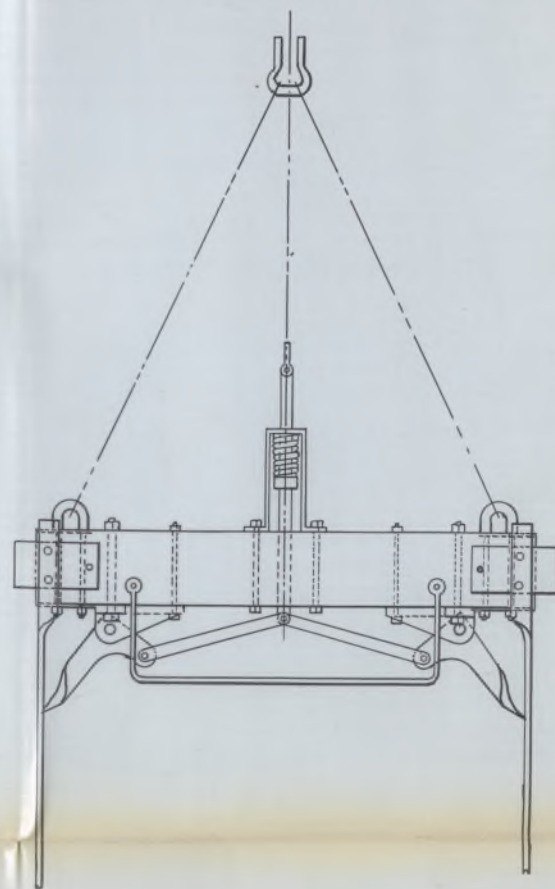


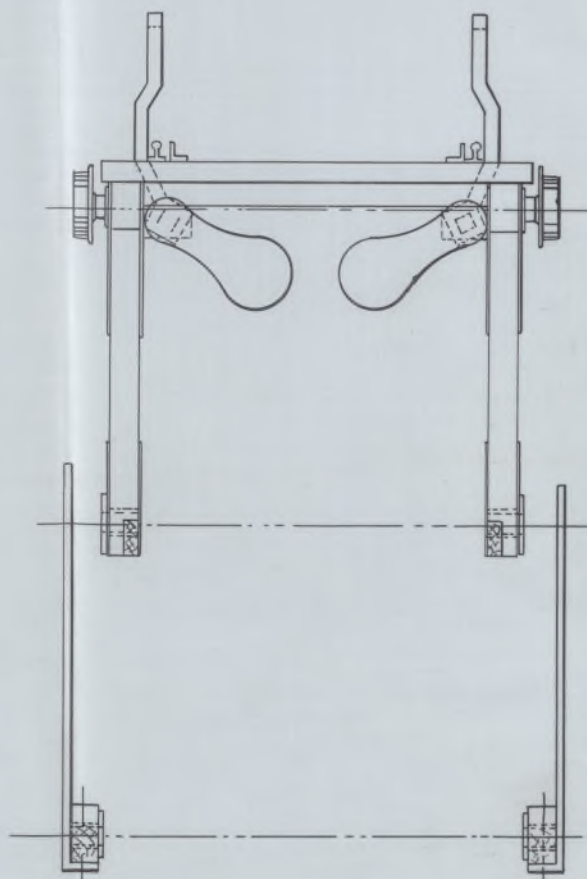
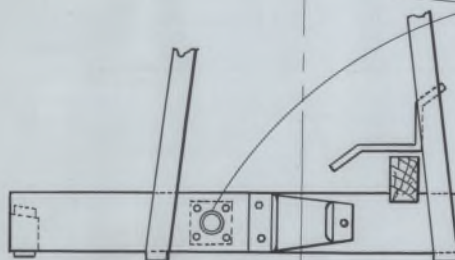
FIG. 17

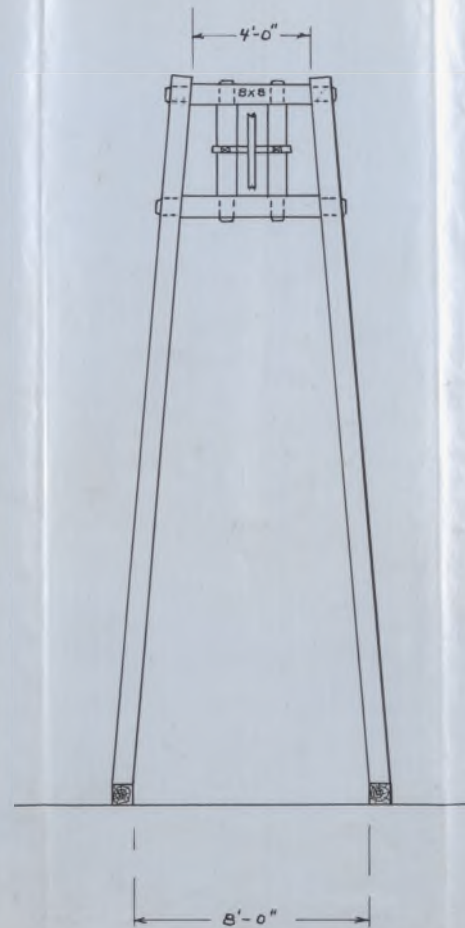
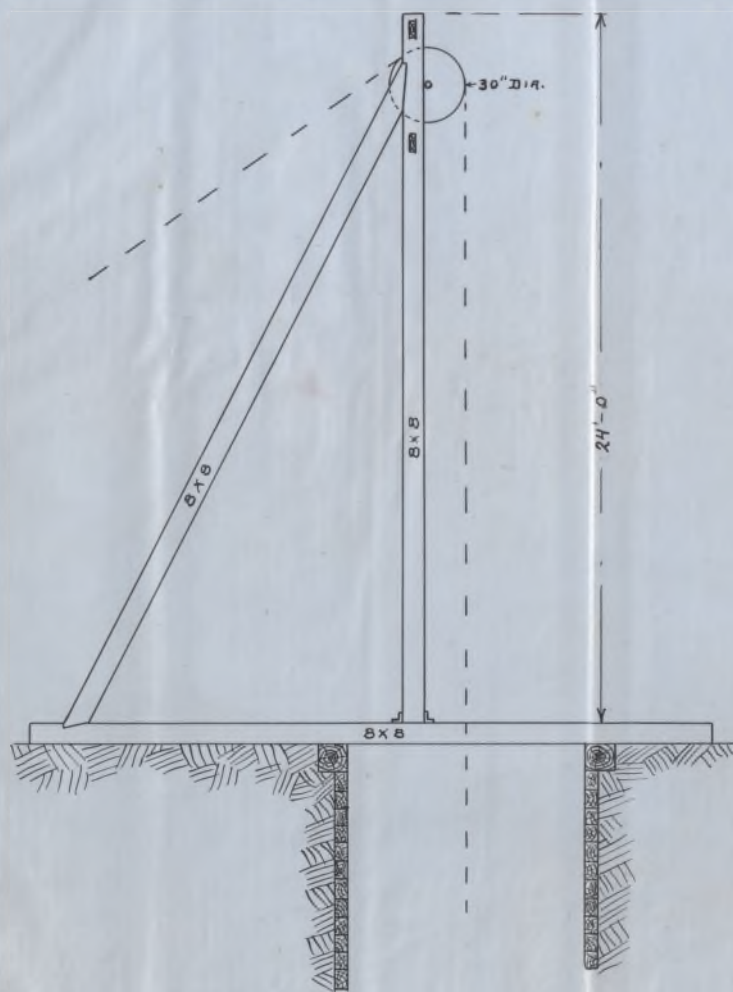


BOND'S PATENT
SELF DUMPING CAGE



Note: When Cage is Assembled,
These Castings are on
the same Shaft.





SINKING HEAD FRAME.

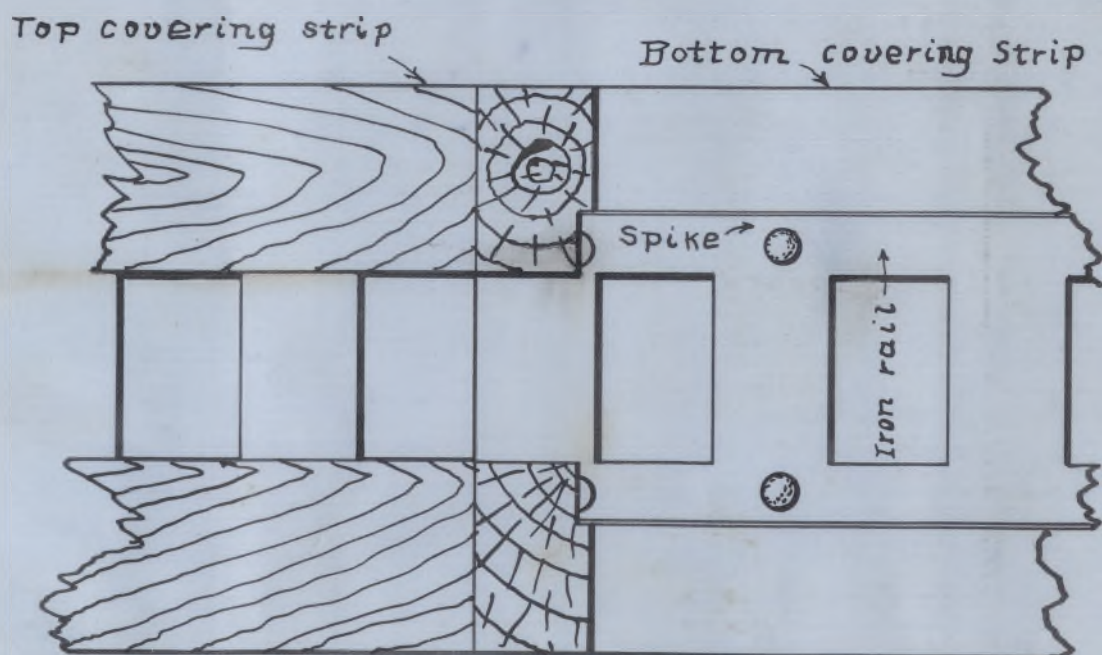
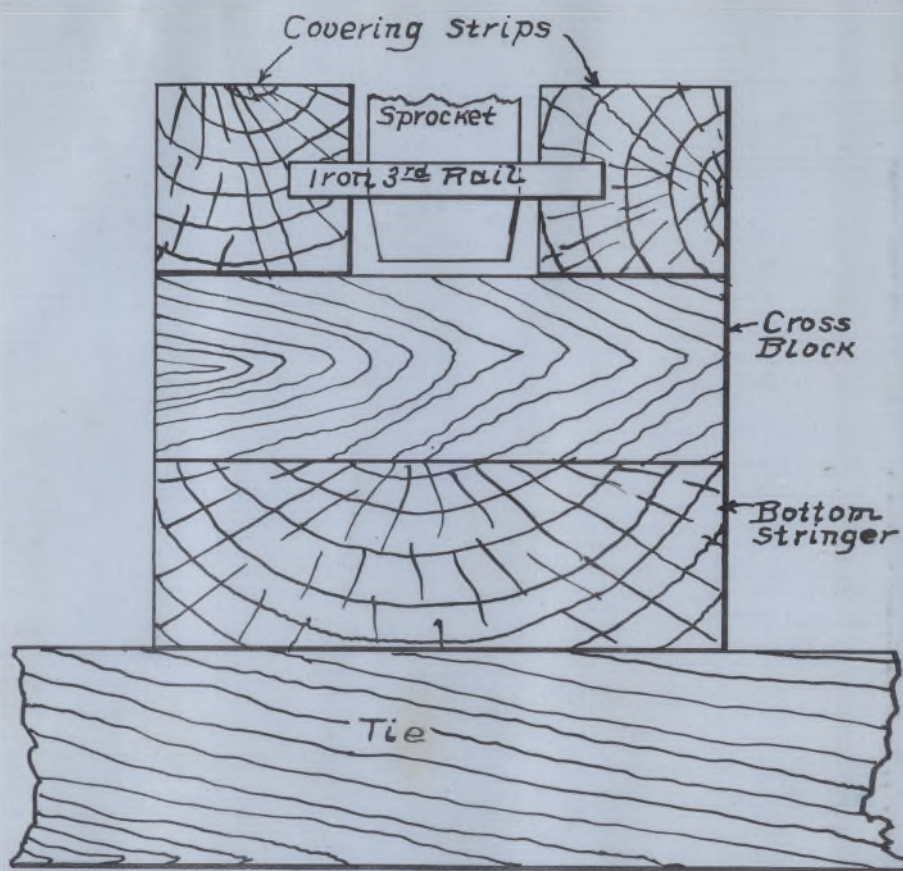


FIG. 20

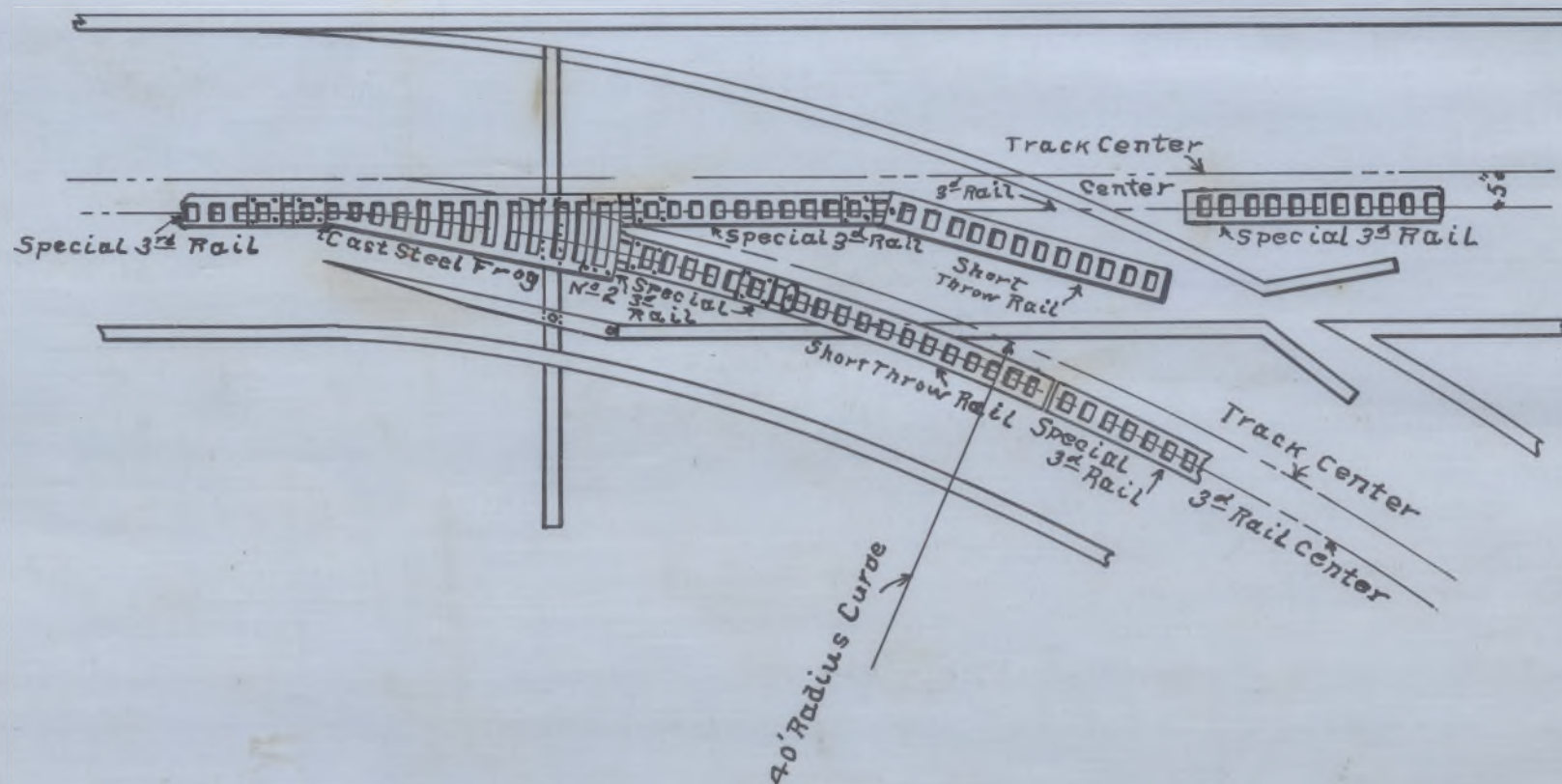


FIG. 21

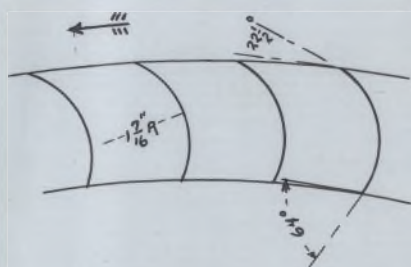
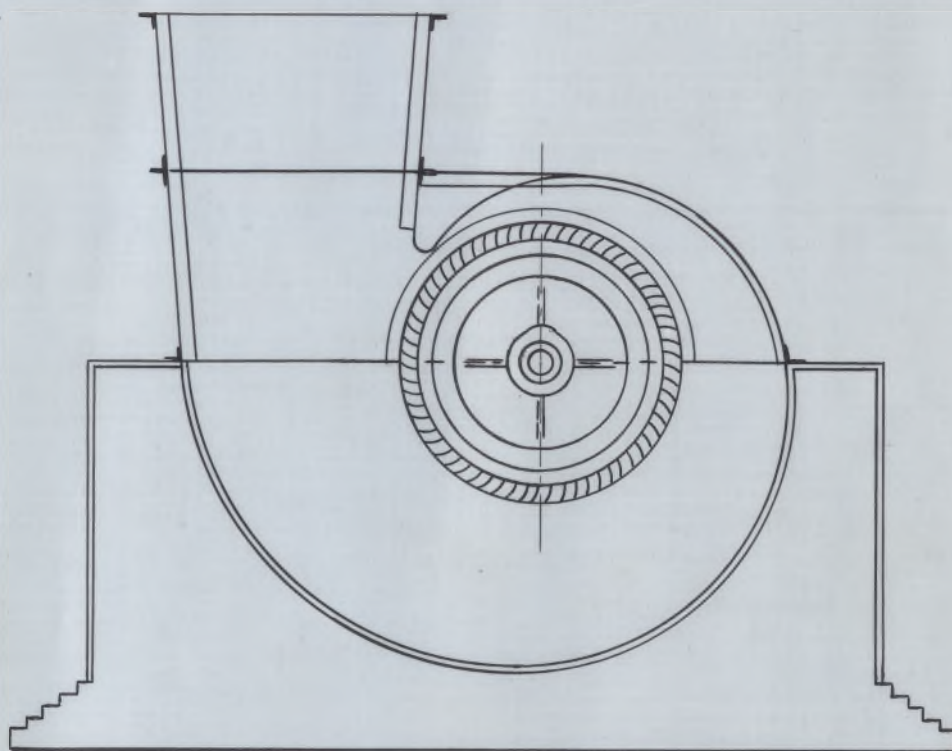


FIG. 22

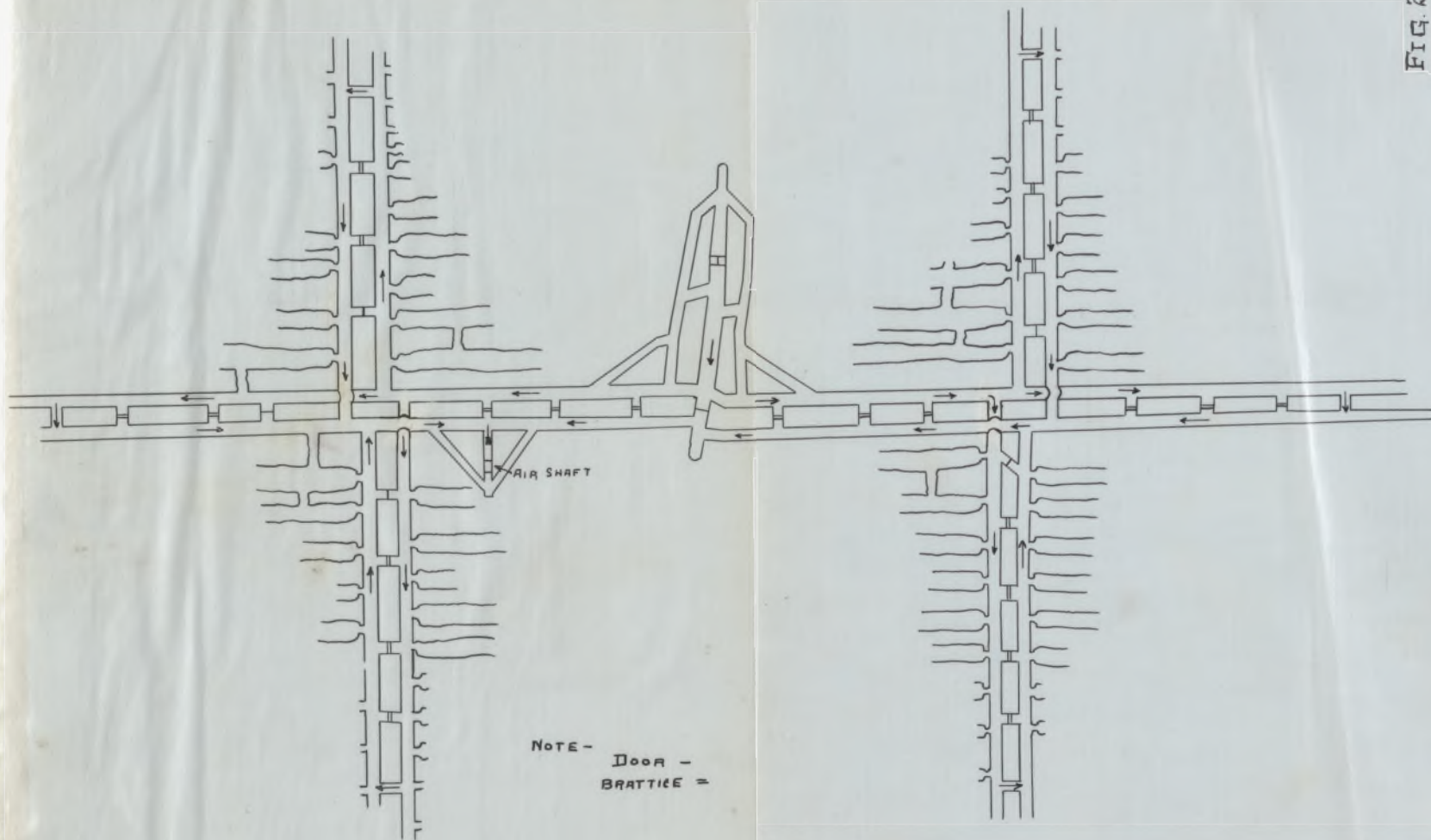


FIG. 23